TRANSACTIONS

of the

Royal Geographical Society of Australasia (Queensland).

REPORTS OF THE GREAT BARRIER REEF COMMITTEE.

VOL. I.

ISSUED 13th JULY, 1925.

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Edited by Dr. J. P. THOMSON, C.B.E., Hon. General Secretary, and by C. HEDLEY, F.L.S., Scientific Director of the Investigations of the Great Barrier Reef Committee.

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Introduction.

FOLLOWING an address by Professor H. C. Richards, D.Sc., on "Problems of the Great Barrier Reef," given to the Society at the April meeting in 1922, the President and Council of the Society decided that steps should be taken to place the matter before cognate bodies and other public institutions in Australasia and Great Britain, with the view of obtaining their support and co-operation in organising a movement for the investigation of that remarkable reef structure. Accordingly an invitation to participate and setting forth the purpose and scope of the projected investigation, accompanied by a copy of Professor Richards's address, was sent out to the Australian National Research Council, the Australasian Association for the Advancement of Science, the Commonwealth Institute of Science and Industry, the Commonwealth Department of Navigation, the Royal Society of Queensland, Queensland Field Naturalists' Club, Institute of Engineers (Queensland Branch), University of Queensland, Queensland Museum, Geological Survey of Queensland, Survey Department of Queensland, Marine Department of Queensland, Harbour Board of Rockhampton, Harbour Board of Townsville, Harbour Board of Cairns, Royal Society of New South Wales, Linnean Society of New South Wales, University of Sydney, Australian Museum (Sydney), Geological Survey of New South Wales, Royal Society of Victoria, University of Melbourne, National Museum (Melbourne), Royal Society of South Australia, Royal Geographical Society of Australasia (Adelaide Branch), University of Adelaide, Adelaide Museum, Royal Society of Western Australia, University of Western Australia, Western Australian Museum, Royal Society of Tasmania, University of Tasmania, Tasmanian Museum (Hobart), Geological Survey of Papua, New Zealand Institute of Science and Technology, the University of New Zealand, and the British Museum (London).

In response to the invitation, the Society has been notified of the appointment of about sixty representatives in all.

Encouraged by this gratifying support, a meeting of the local co-operators was convened and that widely representative body now known as the Great Barrier Reef Committee was instituted to investigate the origin, growth, and natural resources of the Great Barrier Reef of Australia.

The chairmanship of this organisation naturally devolved upon the President of the Society (His Excellency the Rt. Hon. Sir Matthew Nathan, G.C.M.G., F.R.G.S.); and for the dual position of Vice-Chairman and Hon. Secretary, Professor H. C. Richards, D.Sc., was selected, the first meeting being held on 15th September, 1922.

In due course and after a workable plan of investigation had been formulated, sub-committees were constituted to take charge of the separate sections of coastal physiography, oceanography, geology, zoology, botany, and economics.

After full consideration the Committee decided to limit the area of investigation on the south by the State border range, on the east by the Great Barrier Reef, on the north by the Territory of Papua, and on the west, for physiographic purposes only, by the watershed of the coastal and western streams of Queensland.

From the start it was fully recognised that in any movement of the kind the financial question would be a matter of very great importance, as very little work could be done over such an enormously large area without available funds. An appeal in this regard was therefore made to various Governments, commercial firms, scientific institutions, and individuals, the response being liberal. The Universities of Sydney and Queensland agreed to contribute £100 a year each for three years. Various private donors have made liberal contributions, while the Government of Queensland especially encouraged the movement by subsidising the generous subscriptions at the rate of pound for pound up to a maximum of £500 for each of five years. As a result of Sir Matthew Nathan's recent visit to Sydney and Melbourne, the Governor-General (Lord Forster, Patron of the Society), the Governor of Victoria (The Earl of Stradbroke), and the Governor of New South Wales (Admiral Sir Dudley de Chair) have shown their practical sympathy with the movement by the offer of support.

The public have been kept informed of the progress of the movement through newspaper articles and popular science lectures. The Committee also prepared a popular illustrated booklet on the Great Barrier Reef, which was published by the Queensland Tourist Bureau.

Early in 1923 the Director of the Commonwealth Lighthouse Service kindly invited the Committee to nominate two of their members to accompany his vessel, the *Karuah,* on a tour of inspection. This invitation was accepted on behalf of Prof. Richards and Mr. Hedley, who were thus enabled to spend five weeks in June and July in examining the Cape York Peninsula. The results of this excursion form the first scientific fruits of the Committee's work, and are published in the present volume.

Under the auspices of the Great Barrier Reef Committee, and as guests of the Government of Queensland, a distinguished party from the Pan-Pacific Congress visited the Reef in September, 1923. Association of so many specialists from abroad, and discussions of coral problems on the spot, were mutually profitable to all who had the privilege of joining the excursion.

By the end of 1923 the Committee had progressed so far that it was able to act on the recommendation of the Chairman to appoint a full-time scientific director, who should carry out investigations and co-ordinate the efforts of all those working on the Great Barrier Reef problem.

To this post Mr. Charles Hedley was appointed in February, 1924. He was already familiar with the field, having made several visits to the Reef and written various memoirs on its structure and fauna.

The output of work, in the shape of reports and descriptions, was now increasing fast. To receive the papers contributed through the Great Barrier Reef Committee, it has been decided to open a new series, to be called the "Transactions" of the Royal Geographical Society of Australasia (Queensland).

The following papers, products of the Great Barrier Reef Committee, have already appeared in the "Journal" of this Society:—

Vol. XXXVI., pp. 42-54—

"Problems of the Great Barrier Reef." By H. C. Richards.

Vol. XXXVIII., pp. 1-42—

"The Physiography of the Lower Fitzroy Basin." By F. Jardine.

Vol. XXXVIII., pp. 105-109—

"The Great Barrier Reef of Australia." By H. C. Richards and C. Hedley.

Vol. XXXIX., p. 38—

Movement of Sand Cays. By T. Taylor.

Errata.

Explanation of Plate IV., line 8; Fig. 2 should be Fig. 3.

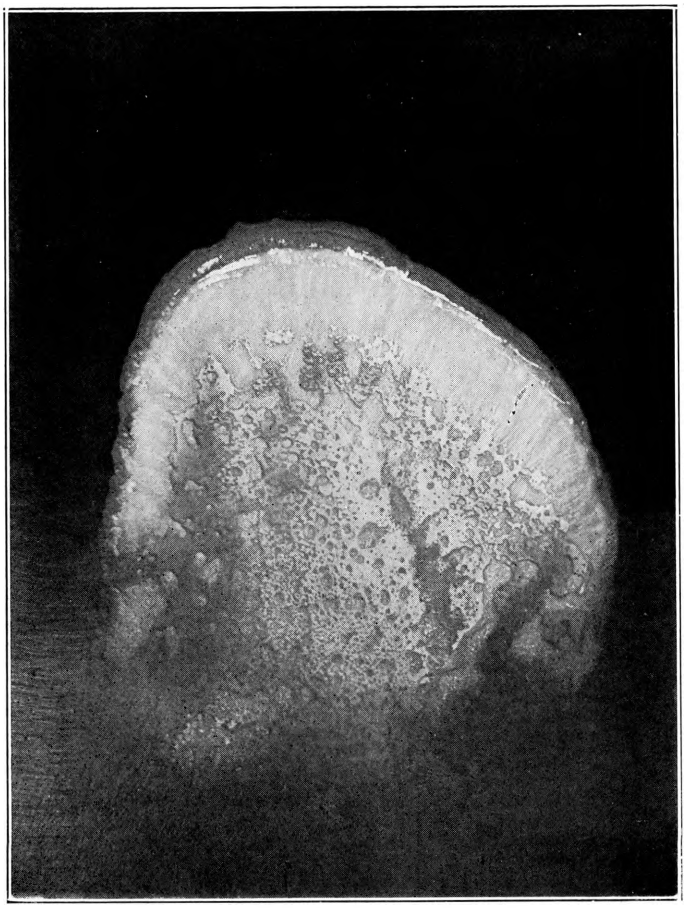
On receipt of a proof, Dr. Pigot kindly sends me the following notes:—

Page 151, line 16—

Other observatories which recorded this disturbance are:—Sydney (Government), Melbourne, Adelaide, Perth, Batavia, Helwan (Cairo).

Page 151, line 28—

Position of the epicentre to be corrected thus:—Lat. 24° S., Long. 154° E.; North-east of Hervey Bay; 980 kilometres nearly N.N.E. of Sydney.



COATES REEF, Lat. 17° 12′ S., Long. 146° 23′ E.

A Coral Reef of the Inner Barrier, photographed from the height of 10,000 feet.

Note the surf represented by a ragged white line; the comparatively solid crescent bank; and the numerous coral heads growing in the lagoon, as described by Dr. Paradice on p. 53.

No such photograph has ever been published before. Now produced by the courtesy of the Royal Australian Navy. Taken from a sea-plane attached to H.M.A.S. "Geranium."

Frontispiece.

Transactions of the Royal Geographical Society of Australasia (Queensland).

VOL. I. 1924. SPECIAL SERIES.

A GEOLOGICAL RECONNAISSANCE IN NORTH QUEENSLAND.

By Professor H. C. RICHARDS, D.Sc., and Mr. C. HEDLEY, F.L.S.

(Two Plates and eight Text Figures.)

To one familiar with the Great Barrier Reef region and with the views which have been expressed by previous investigators in this field, it becomes clear that a proper understanding of the origin, thickness, and age of this unique geographical feature would be much helped by the correct interpretation of—

(*a*) The manner in which the foundation or platform, on which is built the Great Barrier Reef, achieved its present form and position; and

(*b*) The extent to which the various agents of denudation, subaerial, oceanic, etc., have concurred in the development of that platform.

A consideration of the faulting and warping movements to which Eastern Australia, and especially the coastal regions of Queensland, have been subjected is of fundamental importance in this connection, and any information bearing on these movements is a distinct contribution towards the endpoint.

Anyone who has travelled along the coast and thereby traversed Australia's "Grand Canal," between Cape Capricorn and Thursday Island, is unable to escape the conviction that submergence on a grand scale has gone on, and that there has been in comparatively recent times a small emergence, probably differential in character.

In the winter of 1923 the authors spent about six weeks between Brisbane and Thursday Island, most of which was devoted to the far northern part of the region.* Special consideration was

* The Great Barrier Reef of Australia, Qld. Geog. Jour., xxxviii., 1923, pp. 105-109. Other products of this excursion were a paper read at the Pan-Pacific Science Congress of 1923, by the senior author; a paper on "A new Varanus from Coquet Island, Queensland," by J. R. Kinghorn (Records Australian Museum, xiv., Dec. 1923, pp. 135-137, Pls. XVII-XVIII.); and an investigation by R. H. Cambage (Jour. Roy. Soc. N.S. Wales, 1923) into the Juvenile Foliage of *Acacia humifusa*.

given to the islands in Princess Charlotte Bay and those about Cape York, as it was felt that these places, together with the Cairns area, offered most hope of gaining a correct appreciation of the movements which had operated. The area about Cairns has been dealt with by previous investigators, but few have previously given consideration in the field to the region from Cape Melville to Thursday Island.

Alexander Rattray,† in 1869,[1] was the first, after Jukes, to carry out systematic geological work on this region. His brief paper was an excellent one and, although he appreciated the relationship between the foundering of the region east of Cape York and the base of the Great Barrier Reef, he did not offer any other than general observations.

J. E. Tenison-Woods, in 1880,[2] in his paper on "The Geology of Northern Queensland," dealt with the region he had investigated as far north as Cape Flattery (lat. 15° S.).

In 1892, Haddon, Sollas, and Cole[3] published a memoir on "The Geology of Torres Strait," with particular reference to the volcanic zone.

A consideration of the Admiralty charts shows that the Great Barrier Reef becomes more definite and regular north of Cape Grafton (lat. 16°) and, moreover, it approximates to the coastline both in respect to distance and position more closely between Trinity Bay and Cape Melville (lat. 14°) than elsewhere.

A little north of Cape Melville the reef pursues almost a north and south direction up to Murray and Darnley Islands, near the great north-east channel, while the coastline of Cape York Peninsula is rather north-north-west and south-south-east.

† Alexander Rattray.—So little is known of this early contributor to Queensland Geology that we think a few particulars we have been able to glean are of interest. He graduated in medicine at Edinburgh in 1852, was appointed a naval surgeon in 1863, and retired between 1875 and 1879. Like Huxley, Hooker, Richardson, Coppinger, and so many others, he used the great opportunities of a naval surgeon to engage in scientific research. During his commission on the Australian station he prepared the following papers:— "Notes on the Physical Geography, Climate, and Capabilities of Somerset and the Cape York Peninsula, Australia" (Geogr. Soc. Jour. xxxviii., 1868, pp. 370-411, and Geogr. Soc. Proc. xii., 1868, pp. 313-322); "Notes on the Geology of the Cape York Peninsula, Australia" (Geol. Soc. Quart. Jour., xxv., 1869, pp. 297-305, and Phil. Mag. xxxix., 1870, pp. 383-384). As the result of subsequent commissions he gave an account of the Geology of Fernando Noronha, he discussed the Firolidæ (a group of pelagic mollusca), and he described the effect of change of climate and ship life on the ship's company under his professional care.

The area about Cape Melville and Princess Charlotte Bay, therefore, appears to be a critical one in the Barrier Reef.

As the authors had an unusual opportunity of studying the Flinders Group of Islands, near Princess Charlotte Bay, the advantage was accepted and the following account is offered as bearing on Barrier Reef problems.

THE FLINDERS GROUP OF ISLANDS.

These islands are situated between Princess Charlotte and Bathurst Bays, on the east coast of the Cape York Peninsula.

Two hundred and sixty-five miles to the east-north-east, soundings have indicated a depth of 2,275 fathoms, and such proximity to an abyss does not make for quiescent conditions.

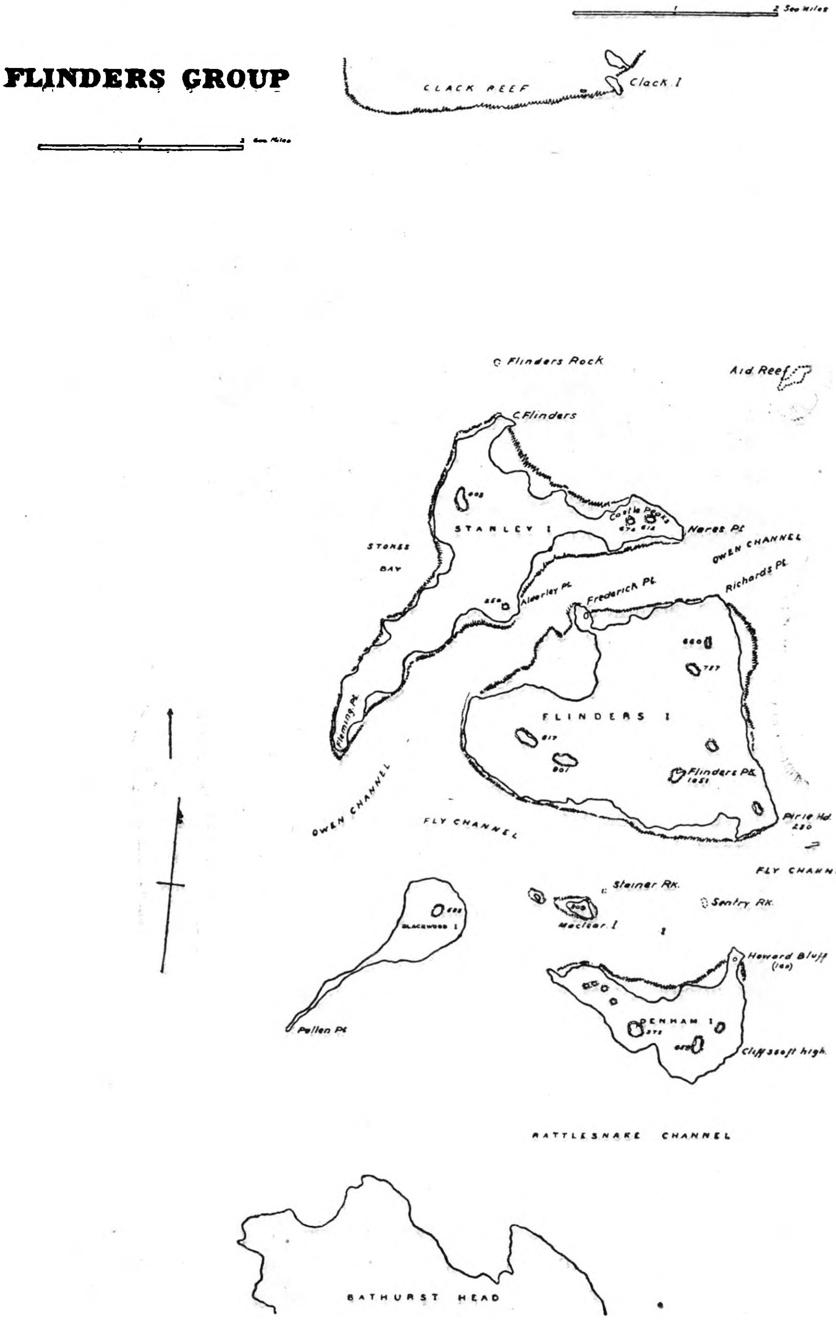
The Flinders Islands are five in number, and extend from 1½ to 7½ miles north of Bathurst Head (Lat. 14° 15′ S., long. 144° 13′ E.).

These islands are composed of sandstone, and are very rugged and clothed with stunted trees and scrub.

To examine the wreck of the ship "Frederick," on the beach of Cape Flinders, Captain P. P. King landed on 14th July, 1819,[4] and he visited the island again on 22nd June, 1821. On the first occasion no people were there, but several native canoes lay on the beach; in one was a turtle harpoon with a detachable head, which he figured in detail on p. 245. Many interesting plants on the hillside rewarded Cunningham, including a *Mimusops, Grevillea gibbosa,* and the new *Melaleuca foliosa.*

On his second visit he had an encounter with the natives, who tried to spear one of his men. Meanwhile, Cunningham had rowed across to Clack Island, which he described as follows:—

> "The base is a coarse, granular, siliceous sandstone, in which large pebbles of quartz and jasper are imbedded. This stratum continues for 16 to 20 feet above the water. For the next 10 feet there is a horizontal stratum of black schistose rock, which was of so soft a consistence that the weather had excavated several tiers of galleries . . . . Immediately above this schistose stratum is a superincumbent mass of sandstone, which appeared to form the upper stratum of the island."



Text Figure 1.

Here was an aboriginal art gallery, in which the natives had painted a long series of birds and animals in red ochre on the black background.

Sixty years afterwards, Dr. R. W. Coppinger[5] anchored on 29th May, 1881, in H.M.S. "Alert," off the Flinders Group. He remarked—

> "The shore on which we landed was covered with large blocks of quartzite stained with oxide or iron, and disseminated among them were many large, irregularly shaped masses of hæmatite."

Next day, in company with Captain Maclear and Professor W. A. Haswell, of Sydney, he crossed over to Clack Island to see the native drawings described by Cunningham. Of these, Dr. Coppinger figured several on his Plate 14.

Rattray, referring to the sandstone which overlies porphyry near Cape York, states on page 299[6] that the sandstone is "prolonged with interruptions onward to Cape Bathurst, where is forms a bold cliff overhanging the sea, as well as the main mass of the adjacent Flinders Group."

Apart from these references, there does not appear to be anything written on these islands except in the "Australian Pilot," printed for the Hydrographic Service of the Admiralty. As Rattray remarked, the sandstone of Bathurst Head is similar to that of the Flinders Group of islands, and it is probably Mesozoic in age—perhaps Jurassic.

In a recent official geological map of Queensland showing the artesian water basin, Mr. Dunstan shows a small area of Jurassic (Walloon) sandstone bordering Bathurst Bay, near Cape Melville; also a strip of Marine Cretaceous (Rolling Downs) on the southern part of Princess Charlotte Bay.

The sandstone of the Flinders Group is very similar to that on Albany Island, etc., near Cape York, and one is justified in regarding it tentatively as Mesozoic, probably Jurassic, in age.

Though Jukes made no mention of it in his account of the voyage, the "Fly" seems to have made a running survey of the Flinders Group. The place names of the Group are associated with the officers of that ship. Thus Owen Channel and Stanley Island evidently refer to Captain Owen Stanley, the commander, after whom the Owen Stanley Range in New Guinea was also called. Captain Blackwood was another officer of H.M.S. "Fly," while Fly Channel commemorated the ship itself.

The Flinders Group of islands represent rather clearly a foundered region which once extended as a cape north from Bathurst Head, and now they separate Bathurst Bay on the east from Princess Charlotte Bay on the west.

Clack Island and King Island, which are both further northward, are no doubt fragments of the once-continuous sandstone terrane. Both islands are composed of sandstone, and the former has a fine, bold cliff over 140 feet high developed along a strike joint. Clack Island's sandstone dips gently to the north, and perhaps still further north the sandstone forms the base of the Great Barrier Reef.

Text Figure 2.

Mount Flinders, on the island of the same name, is the culminating point of the group, and is 1,051 feet above sea level. Flinders Island, the central and largest of the group, in shape is a rough equilateral triangle, each edge of which is approximately 3 miles.

Stanley Island is shaped like a spearhead, with its point directed south-west, the two points on the base of the spearhead being Stanley Hill (403 feet) and Castle Peak (674 feet).

Between Stanley and Flinders Islands is the Owen Channel, of from 6 to 9 fathoms, and about one-half mile in width.

Denham, Blackwood, and Maclear Islands are considerably smaller, and lie between Flinders Island and the mainland.

In approaching the Flinders Group by sea from the north-east, the key to the geological structure of the group is obtained. A denuded anticline, the axis of which is approximately that of Owen Channel, is very clear. Castle Hill shows the anticlinal folding particularly well. (*See* Plate 1, figs. 1 and 2.)

Text Figure 3.

The axis of the anticline follows a direction north-north-east and south-south-west, but further investigation shows the character of the sandstone mass of the islands to be elliptically domed, with the axis of the dome along the north-north-east and south-south-west direction. The axis of the anticline passes between Castle Peak and Stanley Hill, across Owen Channel, through Mount Flinders, and to the east of Blackwood Island.

Consideration of the shore lines on both sides of Owen Channel suggests that the sandstone mass has opened out or cracked roughly along the axis of the anticline, for the peninsulas on the one side fit into the bays on the other side.

It would strike a lay observer that some unusual disruptive force had been in operation here.

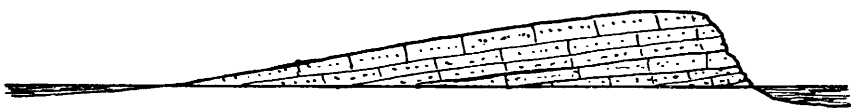
There would no doubt be a series of minor cracks at right angles to the main crack along the axis, and the disposition of the bays on either side of the channel are no doubt governed by these cross fractures.

Evidence of these cracks or faults may be seen just to the south of Stokes Bay, in a cliff section of fine-grained grey sandstone.

The pronounced current bedding characteristic of the sandstone makes it difficult at close quarters to distinguish the real dip of the sandstones, but a general view of the sea-cliffs from a vessel out from the shore or from the adjacent islands shows the stratification quite clearly.

In this way, from any of the high points along the Owen Channel the elliptical domed character is obvious.

The eastern side of Stanley Island, on Owen Channel, shows steep cliffs, the escarpments being due to joint planes, while the slopes on the western side of the island are much more gentle and are really dip slopes.



Text Figure 4.

In accordance with this conception, the base of the cliff sections in Owen Channel should expose the lowest strata, and it is interesting to note that the bottom strata there are rather coarse conglomerate, much coarser than any other outcropping strata seen.

How much further down the sandstone would persist is difficult to suggest, but pebbles up to 4 inches in diameter indicate no great depth.

The pebbles are chert, hornfels, jasper, and quartz, while the sandstone is coarse and comparatively free from mica. Other strata higher up in the series are very rich in white mica, suggesting a granitic source. Although searched for, neither fragments nor boulders of granite were met with in the conglomerate.

If high ground formerly lay to the eastward, in which a cap of metamorphic rocks overlaid a core of granite, then as denudation proceeded, spoil from the hill top might spread a layer of metamorphic pebbles in the foundation of the Flinders Group, while the granite underneath, being opened out at a later stage of denudation, would provide the waste of which the upper strata of sandstone were built.

Some of the sandstone layers have been much impregnated with limonite from percolating solutions, and great flaky layers of limonite material are common. This phenomenon occurs in the similar sandstone on Albany Island, further north.

All stages between normal sandstone and compact limonite may be seen. Some of the limonite is highly concretionary and strongly suggests similar material which occurs so abundantly in the freshwater Walloon (Jurassic) sandstones in south-eastern Queensland. On the other hand these northern ironstones do not contain the fossil plants or fossil-wood fragments, which are so abundant in the Walloon ironstone material in the south. The absence of shaly bands is somewhat remarkable, and no argillaceous deposits were seen in the thickness of the series exposed on Stanley Island—a thickness of nearly 700 feet.

The sandstones appeared to have been laid down in freshwater lakes, and they are composed of the material derived from the granitic rocks such as outcrop at Cape Melville, and from the weathered products of the old metamorphosed Palæozoic rocks which outcrop along the coast near Port Archer and Port Douglas, and which no doubt underlie the sandstone and through which the granite has been intruded. The sandstone is clearly granitic in its character, the cement is felspathic, and mica is abundant, especially in the upper part of the series. The lowest members of the series contain pebbles of jasper, etc., such as one sees very commonly in the above-mentioned old metamorphic rocks.

The current bedding, which is such a pronounced feature, indicates shallow-water conditions; also, the size of the particles supports the view that the grades were steep and the water swiftly flowing. Torrent conditions may have prevailed.

The possibility of the sandstone being a dune deposit has been considered, but the size of the particles and the condition of the pebbles rather discounts such an idea.

Topography of Stanley Island.

A medial ridge extends down the length of the island, which is 4 miles long (north-east—south-west) and 2½ miles wide at the base of the spearhead.

Castle Peaks are the two peaks, one rounded (674 feet) and the other relatively flat (612 feet), while Stanley Hill is 403 feet. The slope is more gentle to the north-west, that is, the dip slope, while the other way the slope is abrupt and cliffs abound.

The gullies are steep and rugged, and each one usually passes up into a steep cliff at its head. Water is very scarce.

The varying compactness of the beds results in pronounced cliffs being developed where the more massive material exists, and of gently sloping ridges and cols where the finer-grained sandstones occur. It is noticeable that the ironstone material invariably occurs on the cols and not on the high ridges.

Fauna and Flora.

One finds on these islands almost a virgin field undefiled by imported pests.

The country is that of open forest, with grass and scrub waist-high in different parts. The growth is stunted throughout, and gives much evidence of the effect of the prevailing south-east wind, which in these latitudes blows with much strength and persistence. The tops of the gum trees are all broken off, the branches are very gnarled, and in no case does the timber exceed a height of more than 25 feet.

Eucalypts of two or three species occur in great abundance, the bloodwoods being the commonest.

The following determinations were made by Mr. C. T. White, F.L.S., the Government Botanist, from specimens collected in the field:—

Eucalyptus exserta F.V.M.

Eucalyptus terminalis F.V.M., Northern Bloodwood.

Greivia polygama Roxb.

Acacia leptocarpa A. Cunn.

Acacia humifusa A. Cunn.

Melaleuca foliosa A. Cunn.

Randia densiflora Benth.

Tabernæmontana orientalis R.Br.

Wrightia saligna F.V.M.

Grevillea gibbosa R.Br.

In addition there were noticed the following:—

Quinine Tree (*Petalostigma quadriloculare*).

Christmas Bush (*Ceratopetalum* sp.).

Umbrella Tree (*Brassaia actinophylla*).

Hisbiscus tiliaceus.

Abutilon.

Sterculiaceous trees, two or three species.

Mangroves, six or seven species.

Palm, one species of Livistona.

There was a total absence of the grass tree.

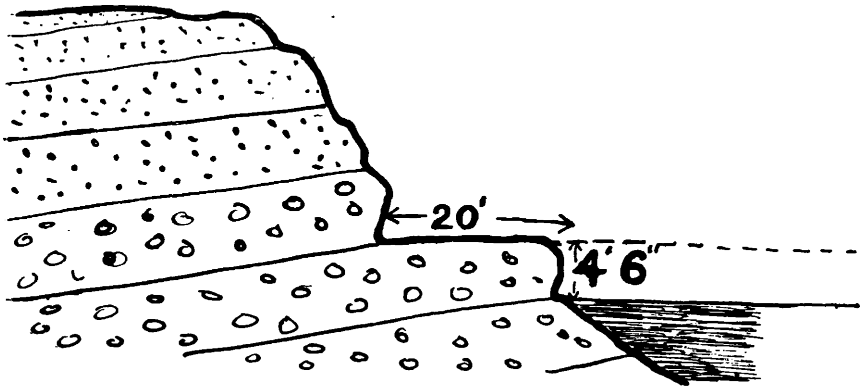
The bark of the bloodwoods gave much evidence of the presence of sharp-clawed climbing animals, probably opossums.

Owing to the scarcity of water, birds are not common. There was, however, a bluish-grey leatherhead and a small kingfisher of brilliant colours—orange brown and blue with black points.

Evidence of Elevation.

All around Stanley Island there may be seen evidence of recent emergence. All the bays are silted up, and sea-cliffs whose bases are now a few feet above the present erosion level occur all around.

In Owen Passage, at one point the present level of erosion is 4 feet 6 inches below the old level, so that there is definite evidence of an emergence of 4 feet 6 inches and, morover, it is comparatively recent, because the new platform has been commenced only.



Text Figure 5.

The old platform carved out of sandstone is at least 20 feet wide to-day, after the falling away of the edge consequent upon the cutting in of the new platform at a lower level. To enable the old platform to be cut, conditions must have been static for some time—a fairly considerable time. The platform in process of formation is very narrow, a matter of 2 or 3 feet only. (*See* Plate 1, fig. 3.)

Alternative readings of what happened are that this elevation might have occurred either—

(*a*) As a single, sudden, and complete act;

(*b*) In an intermittent series of upward jerks;

(*c*) In a gradual steady elevation.

Because a gradual movement or one of small jumps would result in an even, or nearly even, slope, the two latter alternatives are rejected.

From a study of the beach of Island Bay, New Zealand, where the historical earthquake of 1855[7] has left its mark, we interpret the level top and vertical wall of this bench as indicating a sudden leap of several feet, and of quite recent age.

Such movements are of especial importance because of their intimate relation with the being of the Great Barrier Reef.

Any future movement can be measured from the bench mark of H.M.S. "Dart," of 1899, as noted on Chart 3155.*

A history of recent forceful movement is written across the torn mountain of the Flinders Group, one which will be continued in future eventful chapters.

Reconstructing such history from the foregoing observations, we suggest the following sequence of events:—

At one time the Coral Sea was enclosed on the east by land, "the Melanesian Plateau," which reached from Fiji to Papua. In consequence the climate at our position was more arid then than now. To the eastwards of the Flinders Group, but not far away, rose a range of hills with a granitic core and a metamorphic crust. From the waste of this range the Flinders Group sandstones were composed. After the deposition of the sandstone a long unmeasurable period elapsed, during which the ocean probably advanced westwards.

Another chapter opens with the folding of the sandstone. Because a rock so hard and brittle would not easily bend, the process would have been a slow one. Since it has occurred within the present cycle of erosion it is estimated as being Post-Tertiary. Continuation of lateral thrust reared the folding strata into an elongated dome. If the process lasted sufficiently long, some of the outer shell would have been removed by denudation. In the end, pressure action finished by cracking the arch along the centre to shivers. The shattered rock was easily and immediately swept out by rain erosion, leaving a deep and narrow ravine to form the existing Owen Channel.

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* See Austr. Directory, Vol. ii., 1907, 6th edition, pp. 393, 394. "A large datum mark $\overline{\Lambda}$ is cut into the surface of a conspicuous rock by the large waterhole on Flinders Island. This mark is 8 ft. 7 in. above the main level of the sea, and 14 ft. 7 in. above the datum of soundings." But the redetermination of datum marks is an intricate business. Capt. P. Maxwel, R.N., informs us that the procedure would be as follows:—The original tidal observations must be obtained in order to repeat the same general conditions of the season, weather, moons, etc. Three men with complete outfit for the observation of a tide pole continued day and night for at least three months are needed. Finally, if a slight difference in level should be calculated between datum marks of then and now, it would be more likely to be due to different weather conditions, barometric pressure, etc., than to be the result of elevation or subsidence of the land.

Perhaps these occurrences were produced by the dragging of one rock sheet over another. Where contact between two such sheets is smooth and even, a series of regular folds or waves may appear at the surface; but where the bed is irregular the upper sheet moves like a stream descending a rough rapid, where subterranean obstacles pitch the over-riding mass into convulsive shapes, of which the elongated dome, pursuing a crescentic trough and ridge, are characteristic features.

The earth movements which disturbed the Flinders Group seem to have been of two different orders of events. Those of the first series were more severe and gave more imposing results, but involved the superficial strata only.

The second series deals with movements of larger amplitude and reaching deeper into the crust of the earth. These are so recent as probably to be still in progress. Since the sea would not have excavated so deep and winding a sound as Owen Channel, it follows that the stream-carved ravine was depressed until its bed lay 60 feet under the surface of the sea. Thus opened the second chapter. Some time indicators are available, firstly from the deposits of sediment which are now filling in the sound, such as the mangrove flats around Frederick Island; and secondly, from the retreat of the cliffs which once crowned the original ravine on either side. An upward oscillation which succeeded the drowning movement is registered by the elevated platforms of the Owen Channel. This final event brought the geological history of the Flinders Group to a close.

At the Flinders Group is the sharpest break of the Queensland coast. After a fairly continuous north-south course for several hundred miles the coast range of Queensland makes a sudden final rise at Cape Melville, then is broken off abruptly and disappears. After this the coast retreats far to the westward, and when the northerly run is again resumed, it is by another lesser range different in appearance and structure.

One of us already has ventured to suggest that "the abrupt truncation of the meridional coast line at Cape Melville seems as if a whole coast range thence to Cape York might have broken away and slipped into the abyss."[8]

On the high ground about Mount Bellenden Ker dwell an isolated colony of Papuan mountain plants and animals, such as rhododendron and mangosteen, tree kangaroos, and some bower birds. As North Queensland is constructed to-day no passage way exists by which these could cross from the home land to the colony; but if a high coast range, such as runs from Mackay to Cooktown, were continued from Cape Melville to the Murray volcano and thence to New Guinea, the road for migration would be open.

Region between Capes Melville and York, and its Fracture Pattern.

An examination of the map and charts shows that the coast line between these two capes is made up of a succession of bays of varying sizes, but with a wide opening to the north and east and with a base along an east and west line.

These are Princess Charlotte, Lloyd, Weymouth, Temple, Shelburne, Orford, and Newcastle Bays respectively, as one goes northwards.

The capes forming the bold south-eastern corners of each of the bays are Capes Melville, Direction, Weymouth, Fair, Grenville, Orfordness, and Turtle Head respectively.

Of these headlands the first five are bold granitic masses, while the two latter were not examined, but appear to be relatively low-lying sandstone cliffs. Behind the headlands and forming the Cape York Peninsula proper we have a more or less continuous series of flatly-bedded sandstones stretching from Albany Island right down to Indian Head and Mount Saunders, just north of Cooktown.

There appears to be much similarity in this sandstone series throughout its great and wide distribution, and the Flinders Island and Albany Island examples are almost identical.

The sandstone, which is probably Jurassic, has been bedded unconformably upon the old metamorphic Palæozoic rocks or the granitic rocks. The old metamorphic rocks are exposed in the cliff faces along the coast up to and a little beyond Lookout Point (lat. 14° 50′ S.).

From Cape Bowen (lat. 14° 47′ S.) northwards to Cape York, the old Palæozoic rocks are not again exposed in the form of cliff sections, but in their place we find the granitic capes referred to above.

It is above this northernmost exposure of the old metamorphosed Palæozoic rocks that we find this succession of wide open bays, which the authors believe to be the result of a succession of parallel earth fractures along north-south and east-west lines respectively.

W. H. Hobbs[9] has pointed out that a fracture pattern in which the directions are the two cardinal directions and the two intermediate bisecting ones (that is, north-south, east-west, with two sets making angles of 45° with these directions) is probably world-wide as far as the continents are concerned. Suess has shown that in East Central Africa north-south fractures are the most prominent, but later studies by Passarge and Simmer showed that there were four series in the fracture pattern.

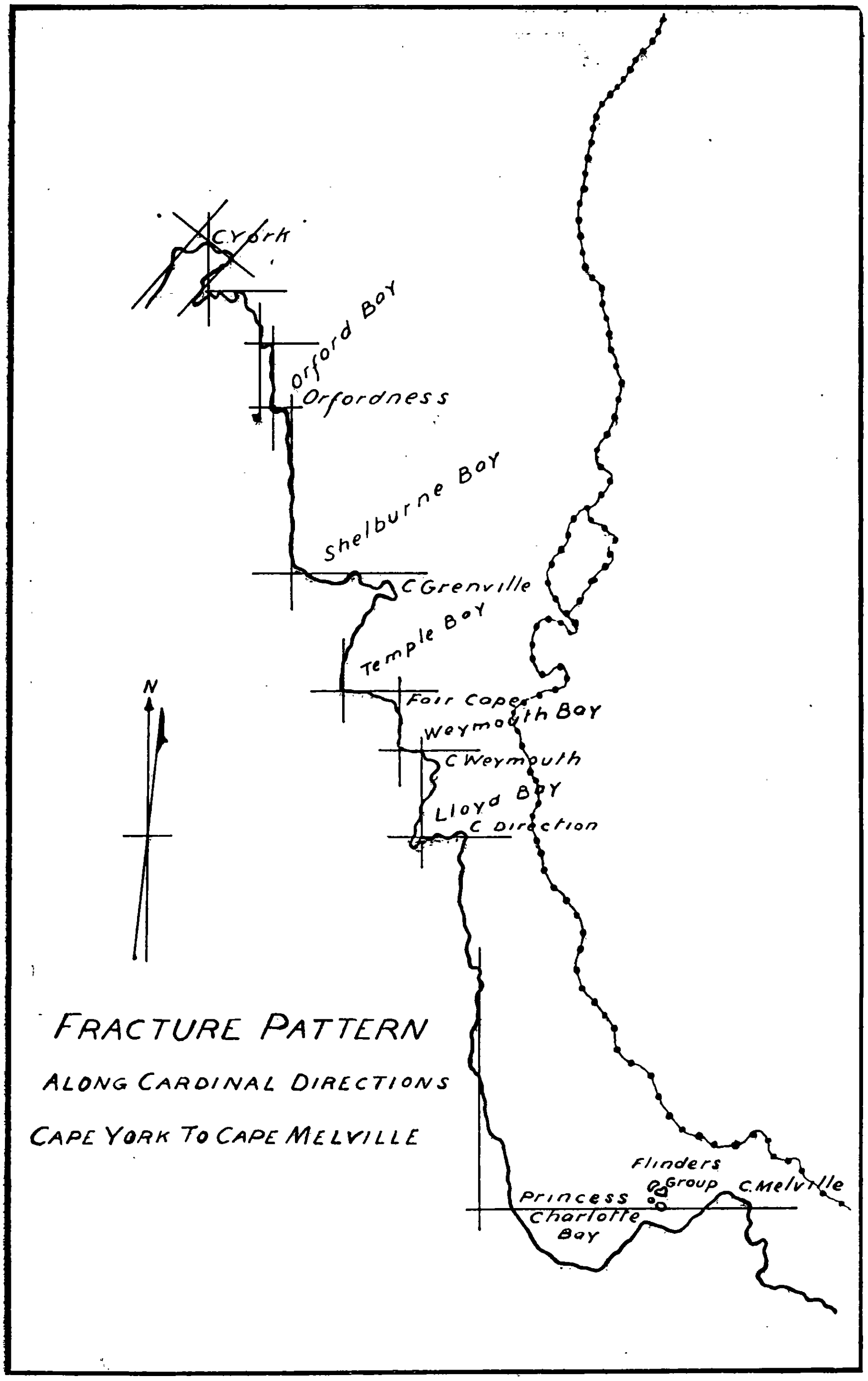
There appears to be a simple fracture pattern developed in the Cape York Peninsula region, between Capes Melville and York, and the cardinal directions have been followed. In this way the succession of bays have been developed.

It will be pointed out later that in the Torres Strait region about Thursday Island the dominant fracture pattern is that along two directions bisecting the cardinal directions.

The granite on Restoration Rock, near Restoration Island, was examined, and its system of joints is as follows:—One set along a north and south line dipping easterly at 45°, and another set along an east and west line dipping southerly at 70° to 80°. The rock is an acid aplitic granite, fine in grain, and composed of quartz, orthoclase, plagioclase, and a little black mica.

It is traversed by more basic porphyry dykes, thin reddish veins of aplite, and by occasional fine veins of quartz. Here and there through the granite there are basic secretions.

Restoration Island is composed of a coarser granite, and except on the north-west side, where Bligh is believed to have landed and where there is an excellent sandy beach, it is composed of a steep granitic mass. The granite is medium to coarse in grain size and has porphyritic crystals of orthoclase set in a base of quartz, plagioclase, and orthoclase and biotite. The granite, when weathered, takes a reddish tinge, and it encloses rounded masses of dark-grey porphyry. Throughout the mass there are acid aplitic veins; also quartz veins.



Text Figure 6.

At Clerke Island, which is one of the Home Islands, just to the east of Cape Grenville, the rock is a dark-coloured quartz felspar porphyry in which the base is hemicrystalline and very flinty in appearance and character.

THE ISLANDS OF TORRES STRAIT.

Rattray has given an account of the islands adjacent to Cape York, Eborac, York, and Albany Islands, but he did not treat with the group of which Thursday Island is the centre, nor with Banks and Mulgrave Islands further to the north.

A. C. Haddon, in 1889,[10] published a very short account of the Torres Strait islands, in which he writes—

> "After having examined a number of the islands in Torres Strait, I can fully confirm the triple division made by Jukes. The lines of longitude 142° 48′ E. and 143° 30′ E. conveniently demarcate these subdivisions."

Albany Island, with the small islands associated with it—Albany Rock and Mai Island—has a foundation of quartz-felspar-porphyry, on which is laid down almost horizontally the freshwater sandstones and grits of supposed Jurassic age. Eborac and York Islands, which are high and rugged, are composed entirely of this porphyry, while Cape York itself is composed of similar material.

Tuesday, Wednesday, Thursday, Friday, Hammond, Goode, and Prince of Wales Islands all appear to be porphyry, as does Booby Island, some 20 miles to the west of Thursday Island. Horn Island has a small area of quartzite of undetermined age.[11]

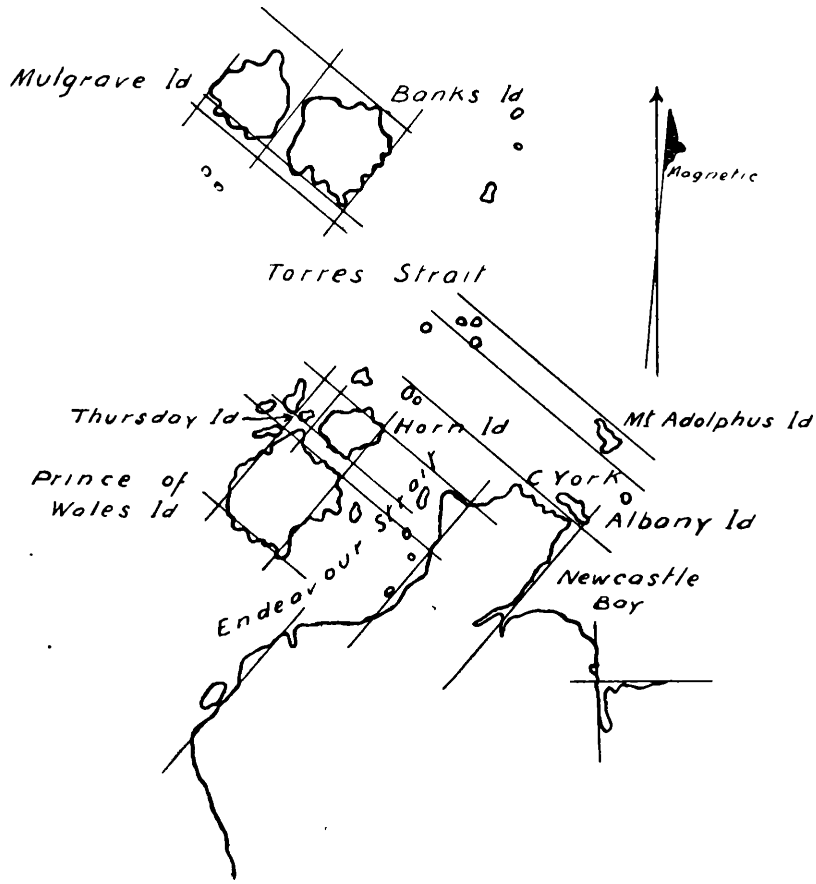
Mt. Adolphus Islands were not visited, but the level top and the character of the rest of the islands as seen from a distance of a few miles indicate that they are composed mainly of porphyry with a sandstone capping. The general relationship of these islands to one another and to the mainland is interesting.

Albany Rock, Mai Island, and Albany Island appear to be part of the apex of Cape York Peninsula, which has broken away along a series of fractures following a north-west and south-east line.

Eborac and York Islands appear to have broken away from Cape York as a result of two sets of fractures developing at right angles, one along a north-west south-east line and the other along a north-east and south-west line.

The character of the rocks on either side of Albany Pass, which is about one-third mile broad and 3 miles long, between Albany Island and the mainland, strongly suggest this fracture.

The shapes and arrangement of the islands centred around Thursday Island also strongly suggest that their partition and formation as separate islands is the result of the development of a fracture pattern along lines bisecting the angles between the cardinal points.



FRACTURE PATTERN

ALONG INTERMEDIATE DIRECTIONS

CAPE YORK AND TORRES STRAIT

Text Figure 7.

Rattray,[12] writing of the sandstone about Albany Pass, states:—

> "Of this, several of the bold cliffs of Albany Island and the opposite mainland consist, and these are so directly opposed, while the bluffs and bays on either side would dovetail so accurately if brought together that we may fairly conjecture that they were once continuous, before the production of the huge cleft which now forms the Albany Pass, or the upheaval of the crystalline rock beneath, which was doubtless the cause of this."

Further, on the same page Rattray writes:—

> "At the north end of Albany Island, where a boss of porphyry protrudes and displaces the overlying sandstone and ironstone, fine examples of chertified clay, ironstone, and quartzite may be seen at their point of contact."

It is clear from these passages that Rattray believed the porphyry to be younger than the sandstone. Such, however, does not appear to be the case. After examining carefully the contacts at Albany Rock, Mai Islet, and Albany Island, the authors are of the opinion that the sandstone was laid down on the weathered and denuded surfaces of the porphyry, and is, therefore, younger and not older than the porphyry.

Rattray furnishes, on pages 300 and 301, a description of the ironstone which is associated with the sandstone on Albany Island and in the neighbourhood of Cape York. He regarded it as "Post-Tertiary," on the advice of W. B. Clarke, "as it contains no gold." Clarke did not actually see the ironstone in the field, but had he done so there is no doubt he would have appreciated the fact that it is part of the sandstone series which has been affected by percolating iron-bearing solutions.

On the north-eastern part of Albany Island there are tremendous fillings along the beach of great masses of honeycombed limonite boulders, out of which has been removed by solution and attrition portions of the sedimentary rocks, which were not replaced by the limonite material.

Albany Island, Mai Islet, Albany Rock, and the Brothers Islands some few miles to the east strongly suggest from their contours and the nature and position of the platforms around them that they have been subjected to a comparatively recent emergence. So variable as to size and time, however, are the tides in this region that it is difficult from a short period of observation to give a definite opinion on such a matter.

The porphyritic rock composing Eborac and York Islands, together with Cape York itself, is a quartz-felspar porphyry with a dark bluish-grey base of hemicrystalline nature. (*See* Plate 2, figs. 1 and 3.

A chemical analysis of this quartz felspar porphyry from Eborac Island has been made for the authors by Mr. S. A. Trout, of the Chemistry Department, University of Queensland, with the following results:—

SiO_2	74·45
Al_2O_3	15·43
Fe_2O_3	0·59
FeO	0·38
MgO	tr.
CaO	0·44
Na_2O	0·97
K_2O	5·87
Loss in ignition	2·47
TiO_2	0·10
P_2O_5	nil.
MnO	nil.
	100·70
Sp. gr.	2·738

The norm as calculated from the chemical analysis is:—

Quartz	45·06
Orthoclase	35·03
Albite	8·38
Anorthite	2·22
Corundum	6·53
Magnetite	0·93
Ilmenite	0·15
Water	2·47
	100·77

The predominance of the alkali felspar over the calc-alkali felspar is very great, and is noteworthy.

Its classification according to the C.I.P.W. system is 1.3.1.2.

On Eborac Island the porphyry has a highly developed platy jointing arranged vertically for the most part, and separated by 3 or 4 inches only. These joints strike N. and S. (*See* Plate, fig. 3), and are intersected by other vertical joints, not so regular or closely associated and striking more or less E. and W. A third system of joints is more or less horizontal, but dips a little to the south. This results in the development of "platforms."

On the summit of Albany Island we found the grave of a pioneer in Australian Geology, D'Oyly Aplin. His tombstone was inscribed:—

"CHRISTOPHER HAY D'OYLY APLIN, P.M.,

Government Resident of Somerset,

Formerly Collector of Customs and Surveyor-General of Labuan,

Formerly Government Geologist in Victoria; also in Southern Queensland.

Died 9th September, 1875, aged 56 years."

This was followed by four lines of laudation.

BOOBY ISLAND.

This is approximately 20 miles west of Thursday Island. It was named by Captain Cook. It is one-third of a mile in diameter, is roughly circular in plan, and shaped like an inverted dish, which is 63 feet high in the centre. The whole island is composed of porphyry, and around its margin there is a fine development of cliffs and caves. Emergence of the island to the extent of a few feet is strongly suggested, especially as the floor of some of the caves, such as the so-called "Post Office Cave," is now dry except during storm periods. These caves are developed along joint planes and result from the mechanical attrition of the porphyry which has been weathered by the percolation of water along the joint planes.

The Booby Island Post Office Cave is about 100 feet long and is tunnel-shaped. (*See* fig. 4, Plate 2.) It is from 15 to 18 feet high at the mouth and approximately the same width. It winds and narrows as it is followed in along the joint plane. It was the custom, before the establishment of any settlement at Somerset or Thursday Island, for sailing ships to use this cave as a depôt for mails, and many interesting impressions may be made out of the walls, including H.M.S. "Salamander," Nov. 2, 1865, so that Alex. Rattray, who was surgeon on the vessel, no doubt visited this historic spot.

Near the summit of the island there are two natural wells, generally full of fresh water. These are caves which are filled with percolated rain-water. Each hole is about 6 feet deep and contains approximately 1,500 gallons. The porphyry on the island exhibits a great deal of jointing, and the rock is weathered so as to give the appearance of breccia. This is, however, merely differential weathering and staining.

Each cave is primarily fixed in its position by a well-developed joint plane, which is more or less normal to the line of breakers.

From a distance the surface of the island appears to be covered with snow, which on examination is seen to be a thin white film of amorphous phosphatic material. Probably many birds have nested on the island for long periods, and the phosphatic coating has resulted from the interaction of the phosphoric acid and the weathered porphyry surface. The film is very thin, about as thick as a sheet of paper, but there is a tendency for it to be thicker in the depressions, to mat the particles together, and to be very white, especially on the surface exposed to the weather.

Although this phosphatic coating occurs over practically the whole island, it is almost completely devoid of vegetation, owing to the absence of soil. On the north-eastern portion of the island, however, there is a marked and rather regular depression like a road cutting, running almost through the island. It is from 30 to 40 feet wide and is due to the weathering of the porphyry along joint planes, or it may be due to the development of a fault plane along a N.E. and S.W. line. In this depressed region there are some trees growing, notably the wild almond, with its large glossy leaves, and there is a certain amount of soil.

The whole of the porphyry on the island gives evidence of much alteration, particularly along the joint planes. If Booby Island at any time had been covered to any extent with guano, the resultant phosphoric acid dissolved in rain water might have been an agent adversely affecting the chemical stability of the rock.

A full and interesting account of Booby Island was given by Moseley.[13] He described it as two-thirds of a mile in circumference and 40 feet high, composed of the same coarse quartz and felspar rock as Wednesday Island. A small cleft runs nearly across the island, sheltering some shrubs and fig trees, besides which the vegetation is reduced to a little grass and a few herbs. The position of the caves suggested elevation to him. He compared Booby Island to Heligoland as a halting place for migrating birds; seven species of land birds, which he names, were shot and three more were seen. Clouds of boobies hovered over the island, and most of the rock was whitened with their droppings. This bird fauna, so abundant in 1874, is now (1923) exterminated.

Spry[14] mentioned—

> "the post office, a rough log shanty in which is kept a record book; for it seems to be a rule with vessels to heave-to here, after the dangers of Torres Strait are passed, and leave their names, and letters to be forwarded by the first vessel."

We may take it, then, that the general form and disposition of the island about and to the west of Cape York, in Torres Strait, suggest that they have resulted from a fracturing of a mass of porphyry along lines at right angles to one another and following directions bisecting the angles between the cardinal points (that is N.E. and S.W., and N.W. and S.E.). Also the porphyry in places appears to have been covered with grits and sandstones laid down under freshwater conditions. In places this sandstone has been denuded away completely, while in other places, as at Albany Rock and Mai Islet, the sandstone has been weathered away only partially.

Albany Pass, between the mainland and Albany Island, furnishes very striking evidence of one of these fractures, as do also each of the channels between the various porphyry islands about Thursday Island.

Text Figure 8.

View of Albany Pass from Eborac Island.

Albany Rock, on which there has recently been erected a lighthouse, affords the best example of the relationship of the sandstone to the porphyry, and shows it resting unconformably upon the surface of the latter.

Rattray, on p. 304, writes—

> "The elevation of Eastern Australia is going on very slowly, because the forces which are at least connected in some way with, if they do not actually induce, it are not in the island itself, but distant, and centred either in New Zealand, New Caledonia, the Indian Archipelago, or the still more remote volcanic districts of the South Pacific."

While Haddon, on page 588, writes—

> "I have satisfied myself that Torres Strait is not an area of recent elevation. No traces of raised beaches or of elevated coral formations were observed. The coral beach-rock on Nagir, recorded by MacGillivray, can, I believe, be accounted for without invoking an elevation hypothesis. Depression of the land is less easy to demonstrate than elevation, but of this also no evidence could be found."

Where two large land masses such as Australia and New Guinea are hinged together is just the point where movement would be expected to cause fracture.

To account for the present distribution of plants and animals, geographers assume that Torres Strait[15] has changed more than once from strait to isthmus. Vertical movements of at least 100 feet, which such alterations involve, would be competent to initiate and extend fracture movement.

Relation of the Outer Barrier to the Underlying Platform.

Dr. T. Wayland Vaughan, in discussing the general question of whether the platform above which offshore reefs rise ante-date or not the presence of the reefs, says the Great Barrier Reef of Australia is definite in its testimony.

Dr. Vaughan then follows this up by showing cross sections south of the reef limits and across the reef-tract, and in these latter he shows two profiles in which the platform projects some miles beyond the reef.

The authors would like to point out that the profiles across the reef tract, as shown in Nos. 4 and 5 of fig. 12 on page 231,[16] are unfortunate in their selection.

It is true that Dr. Vaughan states lower down that—

> "At its northern end the reef appears usually to stand on the seaward edge of the platform or shelf,"

but the same may be said in the regions across which Dr. Vaughan draws his profiles.

In Section 4, drawn from Rodd's Peninsula (lat. 24° 0′ 0″ S.) in direction north 50° east through Fitzroy Reef, the platform is shown projecting between 4 and 5 miles beyond the edge of Fitzroy Reef before it sinks below the 100-fathom line. Inspection of the British Admiralty Chart 345 will show that there are no soundings for more than a mile past Fitzroy Reef, and the dotted line indicating the 100-fathom line is really only hypothetical. In any case it is probably in its correct position, but the absence of any sounding between the edge of the Fitzroy Reef and that line does not mean that the Outer Barrier Reef is not existent there.

Moreover, the line of section is almost at the southern termination of the Great Barrier Reef, where conditions are really becoming very adverse for coral reef formation.

With respect to Section 5, from George's Point, Hinchinbrook Island (lat. 18° 25′ 40″ S.), in a direction north 72° 32′ east, Dr. Vaughan has followed a line which takes him out through Magnetic Passage, a well-known and wide opening through the Great Barrier Reef. In that way the section fails to cut the Outer Barrier on the edge of the platform. If the section had been drawn a little more to the south it would cut Myrmidon Reef, which is above the low spring-tide level and which is less than

1 mile from the 100-fathom line. If the line of section had been drawn a little more north it would have passed through either the Palm Passage or unsounded regions.

Perusal of Chart No. 2349 will verify these statements. The accompanying section was kindly prepared at our suggestion in the office of the Commonwealth Hydrographer from the most recent information, and for reproduction here has been redrawn through the courtesy of the Surveyor-General for Queensland. The horizontal nature of the platform and the close proximity of Myrmidon Reef to the outer edge of this platform or shelf, are clearly shown.

To return from the end to the beginning of this article, as yet nothing is really known of the foundation of the Great Barrier Reef. In the absence of knowledge, directions in which knowledge may be sought are worth suggesting.

Following the doctrine that the master movements of the earth's crust originate in the abysses of the ocean, we now suggest that possibly the 2,000-fathom trough of the Carpenter Deep has controlled the whole history of the Great Barrier Reef, and that pulsations undulating thence have thrust landwards, crushing back the coast and alternately raising and lowering its margin.

A traverse anywhere across tropical Queensland, from west to east, passes gradually from stable to unstable areas. As the Pacific is approached, the surface becomes more contorted and the streams indicate frequent change of drainage. Where the land is lost in the sea the maximum wrench is reached; continuing eastwards to the invisible foundation of the reef it seems probable that the rock masses of which it is composed have endured violence of folding and faulting. Since the outermost islands, which are vestiges of former continental extension, are frequently of granite, it seems a reasonable conjecture that the foundation of the reef is largely granite also. Thrusting has probably played a part, metamorphic strata of Palæozoic age, and also younger rocks, may be infolded with the granite.

GREAT BARRIER REEF

SECTION

From George Point, Hinchinbrook Island (Latitude 18° 28′ 40″ S, Longitude 146° 19′ 50″ E) to open sea

Horizontal Scale of Sea Miles

Vertical Scale of Fathoms

Bearing of Section 77° 00′ 00″ Soundings shown in Fathoms thus - 23 f.

Chart Nº 2349 to be read in conjunction with this Section

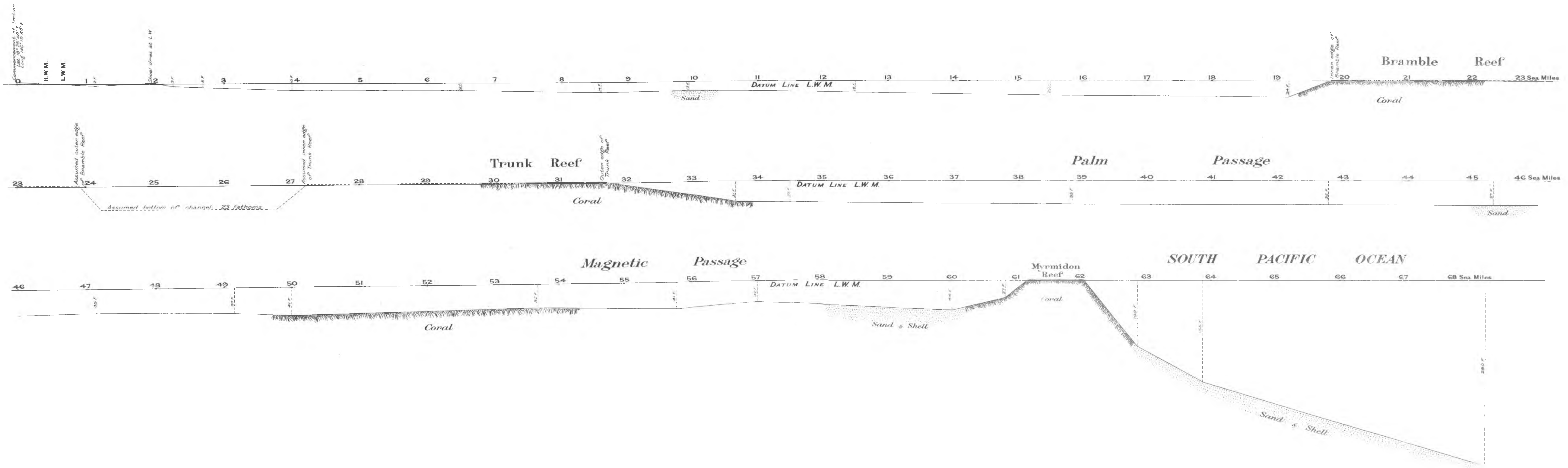


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PLATE 1.—PHOTOGRAPHS OF FLINDERS GROUP OF ISLANDS.

Fig. 1.—View in Owen Channel, looking north-east from near Alderley Point, with the Castle Peaks in the distance.

Fig. 2.—View of Castle Peaks, looking north from the middle of Owen Channel. The gentle inclination of the eastern limb of the anticline is evident.

Fig. 3.—Elevated rock platform, 20 ft. in width, on Stanley Island, at Alderley Point. The platform is 4 ft. 6 in. above present water erosion level, which is shown in the wash of the waves between two fallen blocks. The dark growth in the distance is composed of mangroves growing on the edge of an infilled bay.

Fig. 4.—View of Fleming Point, on Stanley Island, looking south-west from Owen Channel. The south-west dip of the gently-domed sandstone strata may be clearly seen.

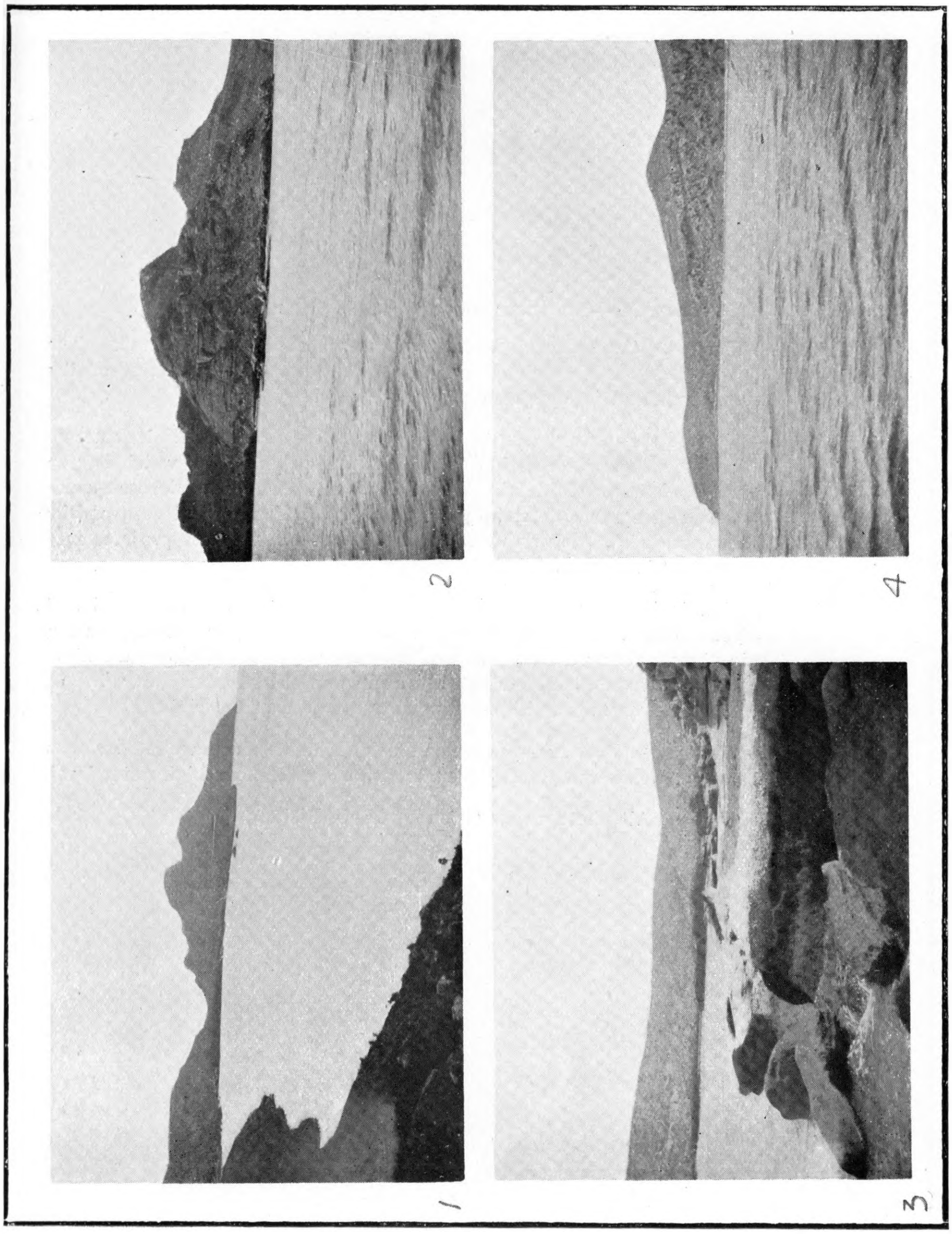
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Plate II.—Photographs of Torres Strait Region.

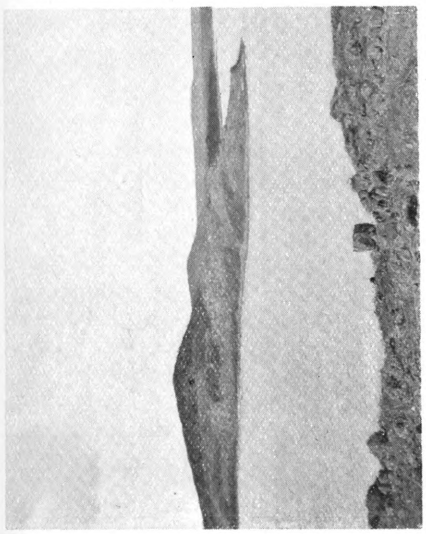
Fig. 1.—View of Cape York, looking south from Eborac Island. The promontory in the middle distance is the northern extremity of the continent and is composed of quartz porphyry.

Fig. 2.—View of the eastern side of Mai Islet, looking north-north-east across the site of the Quetta Rock to Mount Adolphus Island, which is seen in the distance. Mai Islet is composed of horizontally disposed sandstone resting unconformably on porphyry, which is well seen on the adjacent islet, Albany Rock, a small portion of which projects into the right-hand margin of the picture.

Fig. 3.—View looking south-south-west across the ends of Eborac Island and York Island. The platy and almost vertical north and south jointing in the porphyry is seen on the left portion of the photograph, while the storm-tossed boulders of white coral and other material at a height of several feet above high-water mark are seen to the right.

Fig. 4.—View of the Post Office Cave, on Booby Island. The cave is developed along a weathered joint plane, and is now well above high-water level.

All photographs taken by H. C. Richards.



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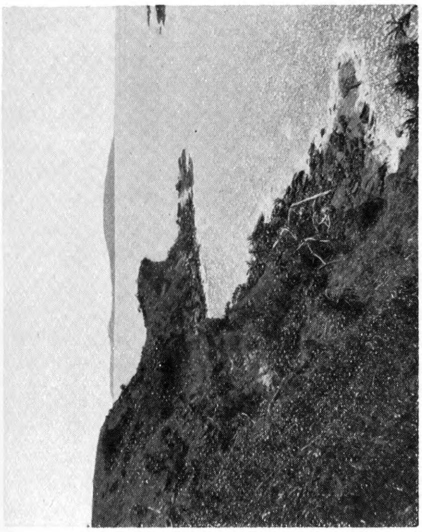

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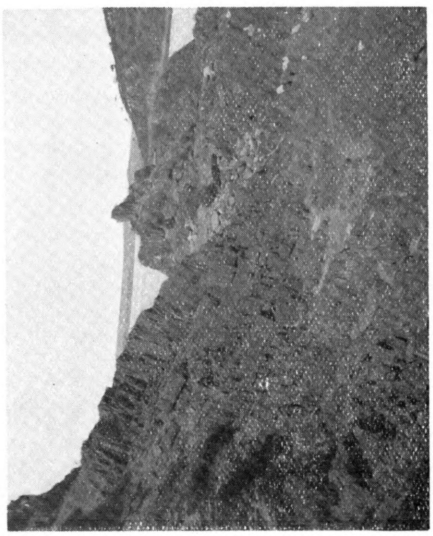

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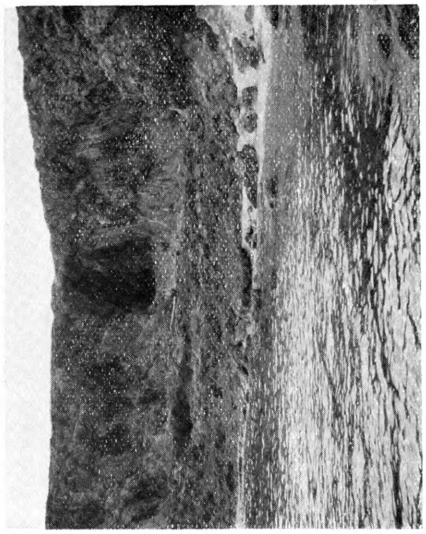

4

RECENT EMERGENCE AT HOLBOURNE ISLAND, GREAT BARRIER REEF.

By P. Marshall, M.A., D.Sc., H. C. Richards, D.Sc., and A. B. Walkom, D.Sc.

(Two Plates.)

Holbourne Island (lat. 19° 44′ S.; long. 148° 22′ E.) situated 15 miles northward from Middle Island, Edgecumbe Bay, and some 20 miles east-north-east of Bowen, Queensland, is best known on account of its phosphatic deposits, which were worked for a short period some few years ago.

During a visit to the Great Barrier Reef region, between Mackay and Cairns, in September, 1923, by a scientific party organised by the Great Barrier Reef Committee, this island was visited, and as it furnished unmistakable signs of emergence the present authors deemed it advisable to record their observations.

The Barrier Reef region, as a whole, shows clear evidence of a considerable submergence, and it is on the edge of this submerged region that the Outer Barrier Coral Reef is believed to have commenced its upward growth. Indisputable evidence[1] of a recent emergence (of the order of 10 feet or so) exists along the eastern coast of New South Wales and Queensland, but anything other than general references to raised beaches, wave-cut platforms, and marine plains is difficult to obtain.

As the island in question is well within the Great Barrier Reef region and is situated in the region between the Outer Barrier and the coastline, evidence of vertical movement is of especial significance in coral reef problems.

The island is variously written Holborn, Holbourn, and Holbourne. It was called after Admiral Francis Holbourne, who commanded the fleet in North America in which Cook served in 1757. It was discovered and named by Captain James Cook, who passed it at a distance on Monday, 4th June, 1770. To zoologists it is famous as the type locality of many marine invertebrates. These were obtained for the famous Godeffroy Museum in 1868 by Frau Amalie Dietrich.

Captain J. Lort Stokes described and illustrated (pp. 332, 333, "Discoveries on Australia," 1846) "a raised beach of 12 feet above high-water mark" on the west side of Cape Upstart, which is about 30 miles west of Holbourne Island.

In 1919 Mr. E. C. Saint-Smith[2] of the Geological Survey of Queensland, reported on the rock phosphate deposits, and in so doing furnished a good account of the physical character of the island. He writes:—

> "In outline the island is rudely in the form of a right-angled triangle, the apex of which (the extreme eastern end) being rough granite cliffs. The sea front of the perpendicular side of the triangle comprises rough granite cliffs along the eastern half, followed by a low beach area bordered by broken coral rock and coral sand. This latter formation continues along the sea front for roughly three-fifths of the base (*i.e.*, western side), the balance of this side being occupied by cliffs of granite. With the exception of about 6 chains of low coral sand and broken coral located in the west-central section of the hypotenuse (*i.e.*, northern side) of the triangle, the area is fronted by granite cliffs throughout. The total extent of the island is about 70 acres, of which approximately 25 acres are occupied by phosphate rock and broken coral, the phosphate-bearing portions totalling, roughly, 20 acres.
>
> "The whole of the eastern half of the island consists of a rough granite ridge, trending mainly east and west, and culminating in a peak situated 14 chains due west of the extreme eastern (or apex) end of the island. The height of this peak is given by Mr. O. L. Amos, authorised surveyor, as being 364 feet above sea level. Another peak of somewhat lower altitude is situated about 11 chains due south of the extreme north-western end of the area, the ridge of which it forms the central knot being some 20 chains long and exhibiting a north-south strike. These two ridges are connected by a low divide (23 feet above sea-level) located about 15 chains east of the centre of the western side of the island."

Further he writes:—

> "The low-lying south-western section of the island, as also a similar small low area to the northward of the low divide above-mentioned, is occupied by more or less phosphatised coral rock, usually overlain by some 2 feet of soil composed largely of guano, with at times lesser amounts of granitic detritus resulting from the denudation of the surrounding ridges. A limited quantity of decayed vegetable matter is also incorporated in the material constituting the overburden."

With reference to the emergence, Mr. Saint-Smith writes:—

> "The existence of several feet in thickness of broken coral rock here is readily accounted for when it is remembered that a (geologically) recent regional uplift, usually estimated at about 15 feet, has been proved to have taken place along the eastern portion of the Australian continent. At Holbourne Island the average thickness of phosphatised coral is between 9 and 10 feet, though occasionally slightly greater depths have been proved in some of the trial shafts sunk."

The island is chiefly composed of a fine to medium-grained granite, light pink to grey in colour, traversed by several fine-grained dark-bluish grey felsitic dykes similar in appearance to those which occur at Flat Top Island, Gloucester Island, and Townsville.

The evidence in favour of emergence consists of:—

(1) Raised beaches;

(2) Caves in the cliffs above the present sea-level;

(3) Elevated fringing coral reef which is now dead.

The extent of the emergence on the south-western side of the island appears to have been one of from 4 to 5 feet.

On the raised beach on the south-western side there is an abundant growth of small trees, mostly of the genera *Pisonia* and *Ficus*. Specimens of the former have a bole whose diameter may be 12 inches, but the Ficus trees do not appear to have been growing very long, especially in comparison with those on the more elevated portions of the island, which have been clothed longer with vegetation.

The coralline material in the raised beaches is exactly like that which forms on the beaches under similar conditions to-day; it has been phosphatised by the percolation of waters which have washed down the slopes of the granitic hills and through the droppings of sea-birds which apparently had rookeries here for a considerable period of time.

It is interesting to note that, although there were very few birds on the island at the time of our visit (September, 1923), Professor W. A. Haswell has since informed us that he visited the island in August or September, 1879, and that he was "specially impressed by the great numbers of birds flying over and making a great din."

The accompanying photographs illustrate the character and extent of the raised beach.

In the cliffs on both sides of the island there are caves, the roofs of which are composed of slope breccia of granitic material, with cementing medium probably phosphatic in part.

The cliffs are now above the ordinary beach level and also above the hurricane beach level. Those on the southern part of the island afford very valuable evidence of emergence, as the caves have resulted very largely from wave action before emergence of the island took place.

The fringing reef on the south-western and southern side shows very clear evidence of an emergence of comparatively very recent date. The large tabular or pancake-shaped masses of *Porites,* so characteristic of the fringing reefs of the Palm Isles and elsewhere, are here entirely dead, there being no live coral growth around their perimeters as in the case in other places. The only growth taking place at present is at about the level of the bases of these masses, where the water is not drained off at low tide. The absence of the live coral is due, no doubt, to the masses standing out above the water to the extent of perhaps 2 feet at low neap tides.

This emergence has been sufficient to bar the progress of most of the broken coral fragments in their course towards the present beach, and has resulted in the building up of a bank of broken coral approximately 200 yards on the seaward side of the present beach. This bank now prevents the area on its shoreward side being completely drained at low tide.

Elevated reefs of this nature were regarded by A. Agassiz[3] as affording, after erosion, the source of "niggerhead" material on the Great Barrier Reef.

The emergence appears to have been quite recent, for the tabular masses are not eroded on the margins to any appreciable extent, and in some cases dead shells of the burrowing clam (*Tridacna crocea*) are still in position.

From an examination of the present beach coralline deposits and a comparison with the phosphatised material in the raised beaches, we are of opinion that the material which was phosphatised was the storm beach accumulation.

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2. Qld. Govt. Mining Jour., 1919, p. 122.

3. Bull. Mus. Comp. Zool., xxviii., No. 4, 1898.

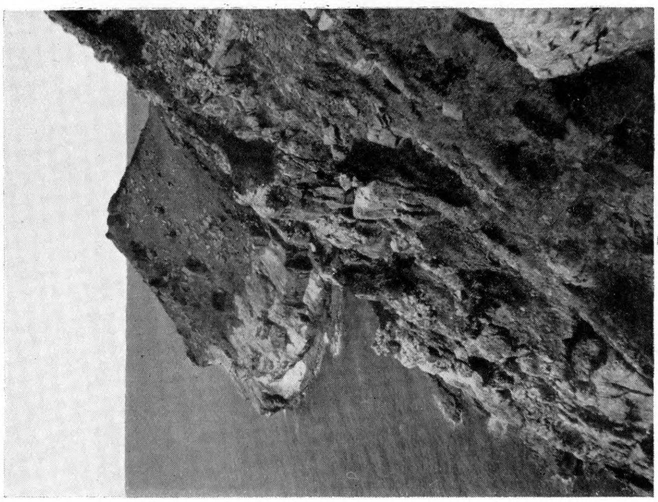
PLATE III.

Fig. 1.—Photograph of Holbourne Island, showing connecting col between the two portions of the island and that portion of the island which has suffered emergence. The figure in the left foreground is at present spring-tide level; the other two figures are at hurricane level, while the cross marks a level where a shaft shows beach coral right up to the surface level.

Photo: D. Pritchard.

Fig. 2.—View of the north-eastern side of Holbourne Island, showing the rugged nature of the granite mass at this point.

Photo: H. C. Richards.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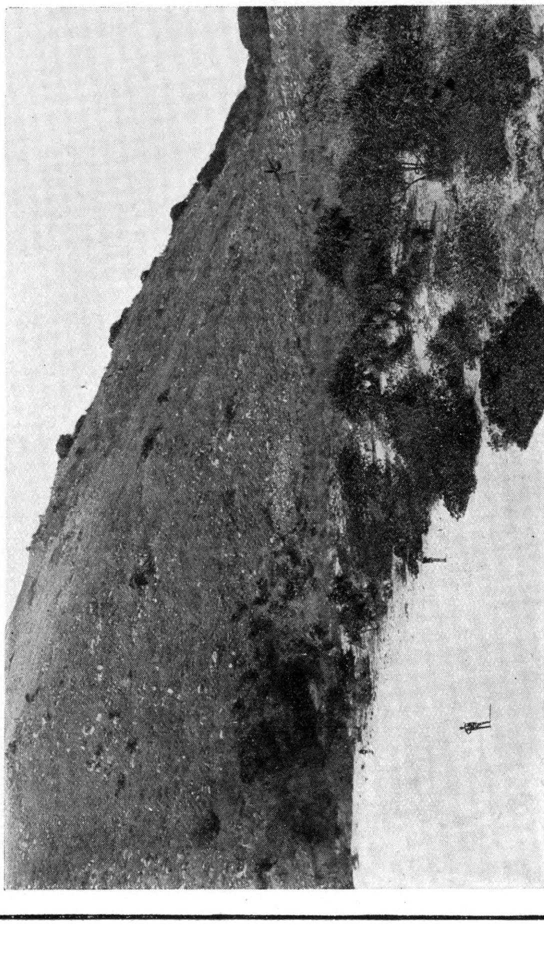
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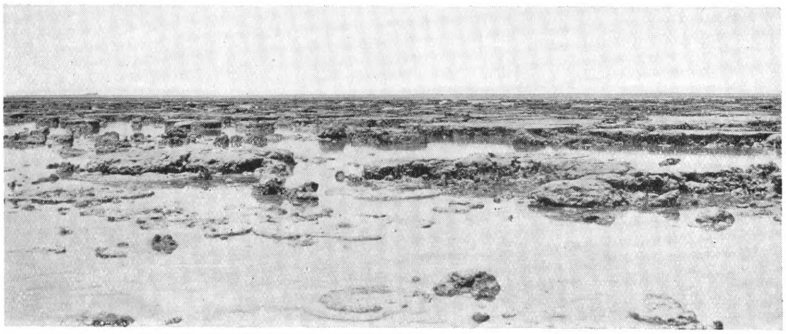
PLATE IV.

Fig. 1.—Elevated coral-reef Holbourne Island. Nares Rock is seen in the distance.

Fig. 2.—One of a series of caves due to marine action and now above hurricane beach level. The brecciated nature of the roof of the cave is clearly seen. Much of the hillside of the island has a similar mantle of breccia.

Fig. 2.—View of the rock phosphate quarry, Holbourne Island.

Photos: D. Pritchard.



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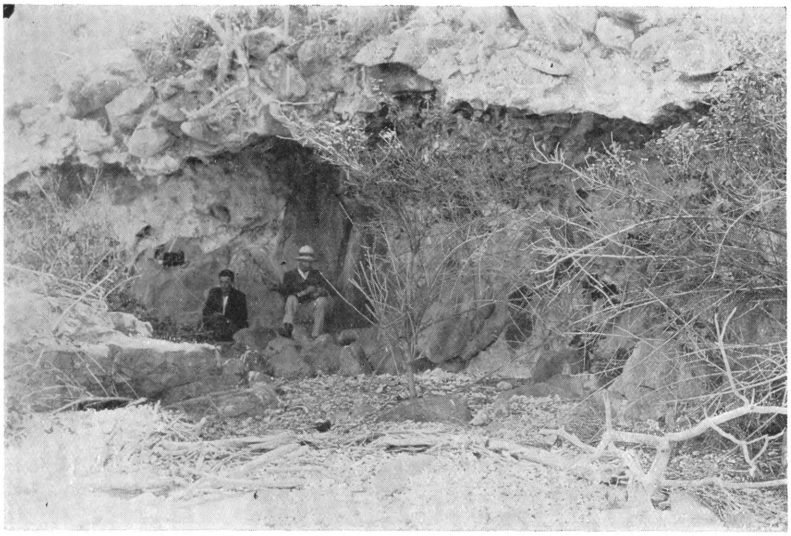

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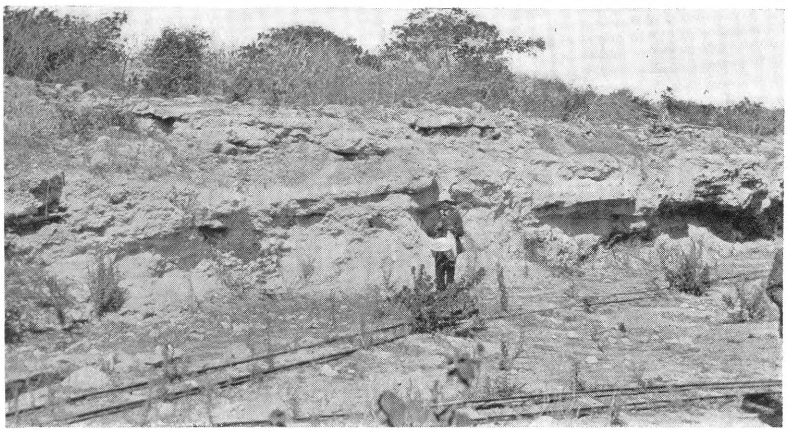


3

THE NATURAL DESTRUCTION OF A CORAL REEF.

By CHARLES HEDLEY, Scientific Director of the Great Barrier Reef Investigations.

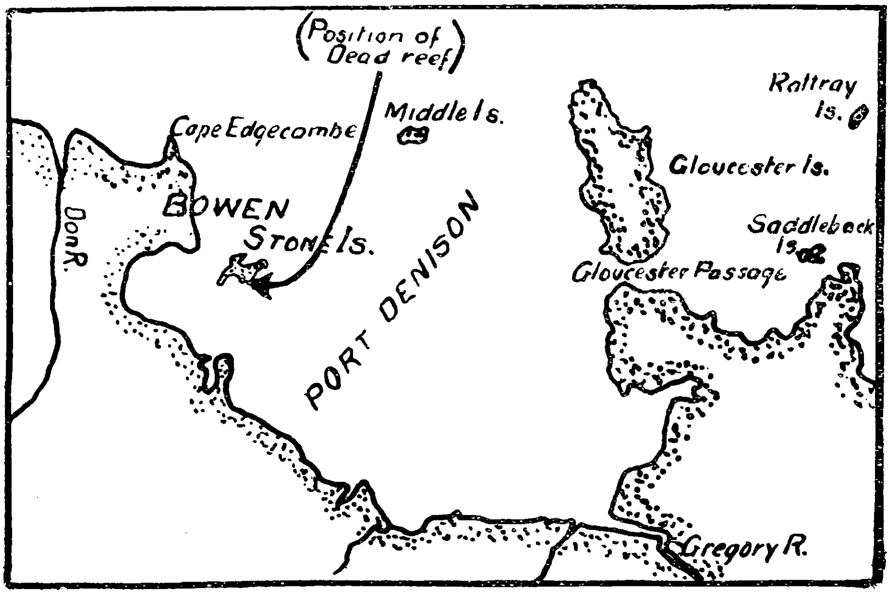
(Plate V.)

Some exquisite pictures of coral reefs, published by Saville Kent, gave to the untravelled student his first idea of how such reefs appear in life. Among the best of these was a series[1] illustrating the reef fringing the south-west corner of Stone Island, near the town of Bowen, in Port Denison, Queensland (lat. 20° S.; long. 148° 15′ E.).

Probably many corals recorded by Brooks and Bernard from Port Denison or the Great Barrier Reef were gathered here by Saville Kent. That writer has noted the following from Stone Island:—*Turbinaria cinerascens, Fungia discus, F. repanda, Goniastrea grayi,* and *Lophoseris cristata.*

A curious presentiment prompted Saville Kent to recommend to posterity the study of this Stone Island Reef as well as of that at Thursday Island, because both were so readily accessible from a town. He suggested[2] that photographs taken after a long interval of time precisely on the same spot and in the same direction as his own would constitute "a measured survey, and thus assist towards ascertaining the future growth."

As the next historian to deal with the topic, I have to make the mournful announcement that this famous, wonderful, and immense structure has now completely vanished. Not only has the coral all died, but every vestige of it, except the foundation, has been swept away. A ruin so complete recalls some tale of ancient, bitter warfare in which it was said that not one stone of the conquered city was left standing upon another and that the conquerers prevented any future revival by sowing their enemies' field with salt.



I was guided to the place where the reef once stood, by Mr. F. H. Rainford, an enthusiastic naturalist resident at Bowen, to whom I am indebted for my first information on the subject. He has seen the reef both in full development and the catastrophe that destroyed it. The testimony of eye-witnesses as to the exact position on which the reef once stood is supported by other evidence. Saville Kent noted landmarks and cross bearings, especially one in which the peak of Saddle-back Island rises in the centre of Gloucester Passage. Kent's Pl. V. No. 1 is taken on this bearing. A photograph published herewith (Plate V.) of the Stone Island Reef was taken by Mr. E. Strange, of Bowen, about 1890. The middle distance is the same as in the above-quoted figure, but the camera stood about 30 yards in front and was turned a little to the left. Here Middle Island appears on the left and the lofty peaks of Gloucester Island on the central and right horizon.

Most investigators who at one time have inspected a reef in healthy growth at another time probably have crossed, but without observing it, the site where such a reef had once stood. It was

Stone Island Reef.

my unique good fortune not only to inspect the razed foundation but to do so with a full knowledge of the reef that formerly stood there. By this happy chance a chapter, hitherto unrelated, can now be written of coral reef ecology.

I spent an afternoon, during a low spring tide, in wading over the place where this reef had been. No coral blocks now remain upstanding; all have been planed away by the waves as if some huge razor had shaved off the coral growth down to low tide level. Where a great coral mass, such as those prominent in the photograph, had once stood, there now appears a block like a great paving stone set in a rough road. This flat stone shows in section the radiations of the coral branching from the core. Between the paving stones are pools of coral sand, and the inequalities between these for hundreds of yards amount to no more than a few inches in height.

With one exception animal life was curiously scarce. The dominant form now in possession of the flat is a species of *Chama*, a shell like an oyster but of a reddish-brown colour, a little larger than a walnut, one valve a cup, the other a flat lid, set tilted on edge and distributed at the rate of several to the square yard. A *Chama*-studded flat like this was described by Professor Taylor and myself from Cairns Reef.[3] Perhaps further experience may show such flats to be characteristic of planed-down reefs.

After some hours' search through this scene of desolation I found two small lumps of *Porites mayori* alive, and no other living coral. But some comparatively fresh coral thrown up along high-tide mark suggests that in deeper water, off the edge of the reef, the coral is now recovering. Such soft corals as *Lobophyton* and *Sarcophyton* were conspicuously absent. Except *Chama,* the mollusca were poorly represented. I found two or three small clams, *Tridacna crocea,* alive, and several others dead. The echinodermata were represented by a few scattered *Holuthuria.* The crustacea were almost confined to small gregarious hermit crabs carrying small shells. At low and high tide I noticed a few barnacles.

A small gregarious brick-red sponge ½ in. in diameter appeared to be perforating the dead coral.

In contrast with this depauperated fauna the algæ were unusually abundant, both as to species and individuals. As a rule algæ are infrequent and inconspicuous on a coral reef. A large collection of these seaweeds were gathered and handed to Mr. Cyril White, Government Botanist, who hopes to supply a report on them later.

The seaweeds and coral are antithetical to each other, the weeds making the ground foul for coral by leaving to the corals no clean gritty surface to perch upon, so that the coral will be unable to regain this site while the weeds are in possession of it. But the cycle will run its course; when the algal complex now in possession dies down the corals will resume their heritage, as one crop follows another.

An explanation which was given to me by Mr. Rainford, and which I fully accept, of this destruction is as follows:—During the cyclone of 1918 so heavy a fall of rain happened that a thick layer of fresh water floated far out on the surface of the sea. When the low tide fell, this surface water sank till the whole reef was immersed in it. Then every living thing that had dwelt there —corals, worms, shell-fish, and crabs, died immediately. Putrifaction from these enlarged the zone of destruction. This slaughter reached as deep as 10 ft. below mean tide level.

Mr. Rainford related that round a beacon in front of the beach at Bowen there existed, before the cyclone, a half-acre patch of coral, chiefly stagshorn, just covered at the lowest spring tide. Not only was all this mass of coral killed in 1918, but the reef rapidly disintegrated, and for many months the opposite beach was strewn with fragments of the dead coral. Now all the coral round the beacon has disappeared, and the water is much deeper.

My informant remarked that the area of destruction extended as far as Armit Island, 20 miles away, and that in 1921 he found the coral on Holbourne Island dead.

I am indebted to the kindness of Mr. G. G. Bond, Meteorologist for Queensland, for some interesting particulars of this storm. The hurricane of 1918, now named the Mackay Cyclone, was remarkable both for the magnitude of the area it covered and the maintenance of its intensity for an unusually long period. It reached its height late on the 19th and early on the 20th January, 1918, when the barometer fell below the notating scale, as the centre of disturbance moved westward and crossed the Australian coast a short distance north of Mackay. An extraordinary rainfall followed. During the 22nd, 23rd, and 24th of January 55 in. fell at Mackay, and the total for January reached 85 in.

This storm swept Bowen with reduced force, yet on the 22nd, 23rd, and 24th, 19 in. was recorded there. After the storm passed, a northerly wind drove the water from the flooded Don River down on Stone Island. Railway bridges over the Don and the Burdekin were carried away. It was reported that a passing steamer drew up bucketfuls of fresh water from the sea at a distance of 8 miles from the land.

The Mackay Cyclone was immediately followed by a sceond storm, a milder type of cyclonic disturbance, which also brought torrential rain. On the 27th, 28th, and 29th of January, Bowen received 15 in.; so that in the eight days of 22nd to 29th January a total of 35·7 in. fell at Bowen. It is reported that a little to the north the rainfall was still greater.

On the surface of the sea rain water a yard in depth had fallen; in addition to this the swollen rivers poured out a huge volume.

The full moon occurred on 27th January, and the ensuing spring tide was a low one. Mr. D. Fison, of the Port Office, Brisbane, kindly informs me that the range of the tides at Bowen, as registered by the local pilot, was as follows:—On 25th and 26th January, 8 ft., and on 27th January, 7 ft. 6 in.

It will be obvious that the oceanic and off-shore reefs would be exempt from this particular casualty. To be drowned in fresh water is a fate reserved for the inshore reefs reached by torrential rain and swollen rivers which change the surface of the sea from salt to fresh.

Glancing at this phenomenon from a long distance, there is a suggestion of recurrence. Probably the reef whose destruction is here related was the growth of centuries. Thus the destruction is a record, not clearly decipherable, of weather cycles, indicating that the conditions of rainfall and tide have not recurred here for hundreds of years.

Probably, if literature was carefully combed, many cases like the subject of this paper might be found recorded. So far I have only noticed the following instance:—At the entrance to Port

Dorey, Western New Guinea, Quoy and Gaimard observed[4] two coral reefs which had been killed long before, but which had commenced to revive and which yielded them a few isolated corals, including the new *Goniopora pedunculata.* They suggest that the coral reef had been destroyed by the heavy rainfall of the north-west monsoon.

A similar but not exactly parallel instance was observed at Cocos Island, and has been fully reviewed by Wood-Jones[5]. In 1876 a spring of dark malodorous water broke out and spread over the south-east of the lagoon, completely destroying the coral there. After a lapse of thirty years the coral had only partially recovered its hold on the denuded area, for which the rivalry of the algæ is to some extent responsible.

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1. W. Saville Kent. "The Great Barrier Reef of Australia," 1893, Plates V., VII., IX., X., and XXXI. Stone Island derives its name, as His Excellency Sir Matthew Nathan kindly informs me, from Mr. R. P. Stone, third officer of the schooner "Spitfire," *vide* G. E. Dalrymple, "Report of the Proceedings of the Burdekin Expedition," 1860, pp. 4.11.9.

2. Saville Kent, op. cit., p. 14.

3. Hedley and Taylor. Rep. Austr. Assoc. Adv. Science, xi., 1908, p. 399.

4. Quoy and Gaimard. Voy. Astrolabe, Zool, iv., 1834, pp. 220, 338.

5. Corals and Atolls, 1912, p. 192.

RECORD OF SEA TEMPERATURES OBSERVED AT WILLIS ISLAND DURING THE CYCLONE SEASON OF 1922–1923.

By J. Hogan.

(Communicated by kind permission of Mr. H. A. Hunt, Director of the Commonwealth Bureau of Meteorology).

From the middle of December to the end of March, the coast of Queensland is liable to suffer from destructive hurricanes. In the case of shipping, especially, their effect may be minimised when the direction and intensity of these storms can be foretold. To make the necessary observations and convey warning to the threatened localities, a wireless station has been established on Willis Island, the most southern islet of the Willis Group (lat. 16 deg. 18 min. S., long. 150 deg. E.). An excellent account of the island and its operations has been published by Captain J. K. Davis.[1]

The temperature of the sea at Willis Island during the 1922-23 and 1923-24 cyclone seasons was recorded daily at 7.30 a.m., with the exception of November and December, 1922, when records were made at 8.30 a.m. All observations were made at a point on or off the beach midway down the north-east side of the island according as the tide was high or low. The water at this point varied in depth from approximately 1 foot to 6 feet, and, except on occasions of a very low tide, was much disturbed with surf breaking on the beach, and temperatures taken under such conditions would give a fair indication of the temperature of the water over the reef platform which extended out from that point to a distance of about 1,000 feet and of the ocean waters beyond. With low tides the water, though not disturbed on the surface, was always in motion, flowing parallel to the beach to the north-west or south-east according to the direction of the wind, but owing to its little depth was subject to the heating influence of the sun. This heating influence would diminish as the season advanced beyond January, when the sun rose later.

A second series of observations was made during the 1923-24 season at noon, but only at irregular intervals. In these an attempt

[1] Willis Island: A Storm-warning Station in the Coral Sea; 1923; pp. 1-119, J. K. Davis.

was made to show to what high temperatures the living growths on the reef platform were subjected, especially at times of low tide, when the pools and channels left by the ebbing tide were warmed to an appreciable extent by the hot sun. It was noticed that the inner half of the reef platform, that part subject to exposure to the atmosphere at low tides, was bare of any marine vegetation.

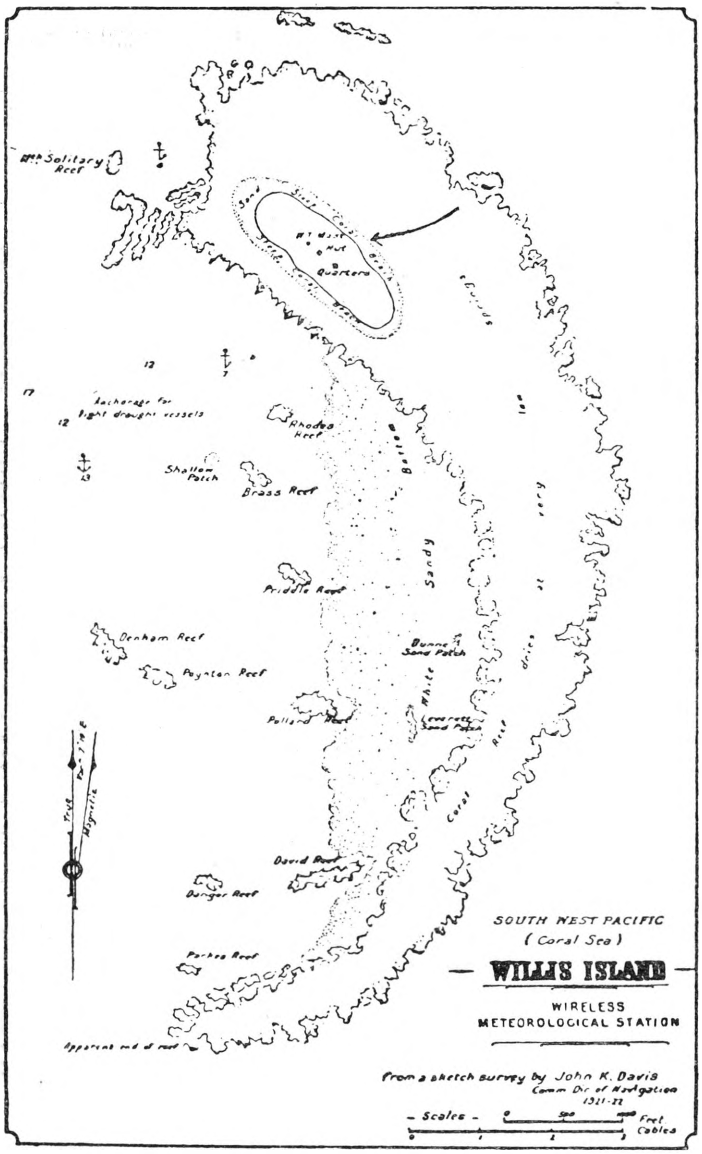
During extraordinary low spring tides towards the end of April of both seasons, and in the middle of the day, much larger areas of the reef platform dried, and a great amount of coral growth near the outer edge was exposed for an hour or so above the surface of the water.

It was observed during the late months of both seasons (March and April) that, irrespective of whether the tide was high or low, the depth of water at noon over the reef platform was invariably small, and, as a contrast, that at 7.30 a.m. was always much greater.

This phenomenon came about gradually during March, and culminated in the extraordinary low spring tides towards the end of April. At about this time the seasons closed and further observations were not made.

Noon, 29th March, 1924.—With a very low tide, temperature of shallow pools and channels left by the ebbing tide was as high as 93·0 degrees in some places. At a distance of more than half way to the reef edge, the temperature in one to two feet of flowing water was 83·5 degrees.

At 1 p.m. on 17th April, 1924, an occasion of very low tide, the temperature of the water at a distance of about half way to the reef edge was as high as 89·0 degrees. The water here was very shallow, and even close to the edge of this reef platform on which the sea was breaking, the water varied in depth from 1 to 1½ feet; and here the temperature was 83·0 degrees.



WILLIS ISLAND (after map by Captain J. K. Davis).

Point indicated by the arrow-head shows where the temperature of the sea was taken. The depth of water here varies from less than 1 foot to about 6 feet. Except at very low tide the surf breaks upon the beach, rendering the observation of temperatures difficult.

TEMPERATURE OF SEA AT WILLIS ISLAND DURING 1922-3 CYCLONE SEASON. DURING NOVEMBER AND DECEMBER, 1922, TEMPERATURE TAKEN AT 8·30 A.M.; FOR OTHER MONTHS, AT 7·30 A.M.

Date.	Temp. taken at 8.30 a.m.		Temp. taken at 7.30 a.m.			
	Nov., 1922.	Dec., 1922.	Jan., 1923.	Feb., 1923.	March, 1923	April, 1923.
1 ..	78·3	80·3	83·2	82·9	81·6	80·3
2 ..	78·0	80·2	83·2	83·1	80·8	80·2
3 ..	78·2	80·3	83·0	82·4	81·2	79·4
4 ..	78·7	80·8	83·0	82·0	81·0	79·1
5 ..	79·0	80·9	81·2	82·0	80·2	79·0
6 ..	79·4	81·0	78·0	81·9	79·6	78·7
7 ..	79·4	81·4	80·3	81·0	80·6	79·1
8 ..	79·7	82·0	82·5	81·0	81·1	79·2
9 ..	79·4	81·4	81·2	81·3	81·9	79·1
10 ..	80·2	81·6	81·8	82·0	82·3	79·2
11 ..	80·3	83·2	83·3	82·0	82·4	79·3
12 ..	80·0	84·6	82·5	81·9	82·0	79·3
13 ..	80·4	83·3	83·0	81·9	82·1	79·3
14 ..	80·1	82·1	82·1	81·8	81·6	79·4
15 ..	80·0	81·9	82·4	81·8	82·0	79·3
16 ..	80·1	81·7	82·0	81·0	82·1	79·5
17 ..	80·7	81·7	82·6	81·0	82·0	79·5
18 ..	80·2	82·1	82·1	81·0	81·7	79·3
19 ..	80·7	83·0	82·0	80·9	81·7	78·8
20 ..	80·2	81·8	82·6	80·6	81·7	78·7
21 ..	80·0	82·5	82·6	80·8	82·1	78·4
22 ..	80·3	82·7	81·9	80·7	81·7	78·2
23 ..	80·8	82·9	81·8	80·8	81·8	78·7
24 ..	81·3	83·5	81·9	80·8	81·9	79·0
25 ..	82·0	83·2	82·0	81·2	81·7	79·0
26 ..	80·8	84·0	82·2	81·2	81·2	79·4
27 ..	81·4	83·4	82·4	81·3	81·3	79·2
28 ..	81·4	83·2	81·0	81·1	81·3	79·0
29 ..	81·0	82·3	82·4	..	81·0	..
30 ..	80·4	83·7	82·1	..	80·9	..
31 ..	..	83·9	82·8	..	81·0	..
Means	80·1	82·3	82·1	81·5	81·5	79·2 (28 days)

Arrived Willis Island 29th Oct., 1922, and commenced taking temperature of sea on 1st Nov. Left Willis Island on 28th April, 1923.

TEMPERATURE OF SEA AT WILLIS ISLAND DURING 1923-4 CYCLONE SEASON.

Date.	Nov., 1923.	December, 1923.		January, 1924.	
	7.30 a.m.	7.30 a.m.	Noon.	7.30 a.m.	Noon.
1	..	79·8	..	81·8	84·9
2	..	79·8	..	81·1	..
3	..	78·6	..	81·7	90·4‡
4	..	78·6	..	81·3	..
5	..	79·1	..	81·4	..
6	..	79·7	..	81·3	83·5
7	..	80·8	..	81·2	84·0
8	..	80·4	..	82·2	84·0
9	..	80·0	..	81·8	84·8
10	..	80·0	..	81·3	85·2
11	..	80·4	..	81·7	86·1
12	..	79·2	..	83·1	..
13	..	79·4	81·8	83·3	..
14	..	80·0	..	83·0	83·9
15	78·9	80·4	82·0	83·0	..
16	78·7	80·7	82·3	82·9	83·7
17	78·1	80·7	84·0*	82·7	..
18	78·9	81·3	..	82·7	..
19	78·2	81·1	83·7†	83·3	..
20	78·8	81·1	84·3	82·1	..
21	78·3	81·9	84·2	82·2	85·0
22	79·2	81·9	83·1	82·2	83·8
23	78·9	81·8	82·9	82·6	83·7
24	79·1	81·8	82·8	82·2	83·8
25	79·0	81·7	84·0	80·2	..
26	78·8	82·1	83·9	81·7	84·7
27	79·1	82·0	84·6	82·2	85·0
28	79·9	81·0	..	80·2	87·0
29	79·9	81·5	..	80·8	88·1
30	80·8	82·2	85·2	81·3	88·5
31	..	81·5	..	82·1	..
Means ..	79·0 (16 days)	80·7	..	82·0	..

* Noon temperature fell from 84·0 deg. at water's edge to 82·2 deg. about 30 yards out; water 1 to 2 feet deep.

† Noon temperature fell to 82·3 deg. about 30 yards out; water 1 to 2 feet deep.

‡ Noon 3rd.—Low tide, very little depth of water, less than 2 feet, 100 yards out, where temperature 84·3 and first signs of vegetation on sea bed.

TEMPERATURE OF THE SEA AT WILLIS ISLAND DURING 1923-4 CYCLONE SEASON.

Date.	FEBRUARY, 1924.		MARCH, 1924.		APRIL, 1924.		MAY, 1924.
	7·30 a.m.	Noon.	7·30 a.m.	Noon.	7·30 a.m.	Noon.	7·30 a.m.
1 ..	82·2	..	83·1	..	82·1	..	80·7
2 ..	82·2	86·4	82·8	..	82·3	..	80·2
3 ..	82·6	..	82·7	..	81·9	..	79·9
4 ..	82·4	..	82·4	..	82·2	..	79·8
5 ..	82·2	..	82·4	85·3	82·2	..	79·7
6 ..	82·0	84·2	82·6	83·9	82·6	..	79·5
7 ..	82·2	84·9	82·1	84·3	82·1	..	79·8
8 ..	82·1	84·7	82·3	84·1	82·6	..	..
9 ..	82·3	85·8	81·5	85·5	82·0	..	..
10 ..	81·8	..	82·7	84·9	82·3	..	..
11 ..	82·1	..	83·2	..	82·4	88·5	..
12 ..	82·8	86·7	..	..	82·1	..	..
13 ..	82·9	..	82·2	..	82·7	..	..
14 ..	82·9	..	82·0	86·2	82·2	..	..
15 ..	82·8	..	82·0	..	81·7	..	..
16 ..	82·8	..	82·0	..	82·0	..	..
17 ..	82·8	..	81·9	..	81·3	..	..
18 ..	82·8	..	81·8	..	81·9	..	..
19 ..	82·9	..	81·9	..	81·9	..	..
20 ..	82·9	..	81·9	..	81·4	..	..
21 ..	82·9	85·0	81·8	82·7	81·5	..	..
22 ..	82·3	..	81·7	82·8	78·9	..	..
23 ..	80·3	..	80·9	82·8	79·6	..	..
24 ..	82·0	..	80·0	83·0	80·8	..	..
25 ..	82·3	85·0	79·7	83·2	81·0	..	..
26 ..	83·0	84·8	79·8	83·8	80·9	..	..
27 ..	82·9	86·4	80·9	..	80·9	..	..
28 ..	83·7	88·7	81·0	..	81·0	..	..
29 ..	82·7	..	81·1	..	81·0	..	..
30 ..	..	..	81·8	..	80·8	..	..
31 ..	..	..	81·9	..	..	..	..
Means ..	82·5	..	81·8	..	81·6	..	..

SEA-BIRDS OF THE GREAT BARRIER REEF.

By W. B. ALEXANDER, M.A., Vice-President of the Royal Australasian Ornithologists Union and Corresponding Fellow of the American Ornithologists Union.

No. 5.

Birds were collected on the islands and reefs off the east coast of Queensland by officers of several of the ships engaged in exploration and survey work during the nineteenth century. Among these were the "Mermaid" and "Bathurst" (Capt. P. P. King) 1819-1821, the "Beagle" (Capts. Wickham and Stokes) 1839-1841, the "Fly" (Capt. Blackwood) 1843-5, the "Rattlesnake" (Capt. Owen Stanley) 1847-1850, the "Challenger" (Capt. Sir G. Nares) 1874, and the "Alert" (Capt. Maclear) 1881.

J. B. Jukes, in his narrative of the voyage of the "Fly," gives a brief account of the colony of sea-birds nesting on First Bunker's Island, in the Capricorn Group, and an illustration showing a similar colony on Lady Elliott Island. He also gives an account of the colony on Raine Island. J. Macgillivray, who was on board the "Fly" and afterwards on the "Rattlesnake," to collect natural history specimens for the Earl of Derby, supplied to Gould accounts of the sea-birds met with on Raine Island and Bramble Cay, Torres Strait, extracts from which are incorporated in the latter's "Handbook of the Birds of Australia," published in 1865. H. N. Moseley, in his "Notes of a Naturalist on the 'Challenger'," again described the bird colony on Raine Island and also gave an account of Booby Island in Torres Strait.

The work of these collectors, specimens obtained by whom were deposited in the British Museum, led to a knowledge of the species of birds found in the region under consideration.

In recent years a number of local ornithologists have paid visits to various portions of the Barrier Reef region and have added greatly to our knowledge of the habits of the birds frequenting it.

The most important of these visits were the expedition to the Capricorn Group undertaken by the Royal Australasian Ornithologists Union in October, 1910, and the series of visits paid to the islands lying off the coast, between Cape York and Cooktown, made by Dr. W. Macgillivray of Broken Hill, N.S.W., and his collector (W. McLennan) in the years 1910, 1911, and

1913. Some information as to the bird-life of the islands in the intervening region has been gained through visits paid by W. McLennan to Upolu Bank and Oyster Cay, off Cairns, by Dudley Le Souef and H. G. Barnard to the Barnard Islands, and by E. M. Cornwall and T. P. Austin to the islands off Mackay. E. J. Banfield during his long residence on Dunk Island studied the birds of that island, and Capt. J. K. Davis during his six months' residence on Willis Island made notes on the birds found there.

The following articles contain the observations of these ornithologists:—"A Visit to the Great Barrier Reef," by T. P. Austin, Emu VII., p. 176; "Narrative of the Expedition to the Islands of the Capricorn Group," by C. Barrett, Emu X., p. 181; "Birds Identified on the Capricorn Group during Expedition of R.A.O.U., 8th to 17th October, 1910," by A. J. Campbell and Capt. S. A. White, Emu X., p. 195; "Along the Great Barrier Reef," by Dr. W. Macgillivray, Emu X., p. 216; "Notes on some North Queensland Birds," by Dr. W. Macgillivray, Emu XIII., p. 132; "Ornithologists in North Queensland," by Dr. W. Macgillivray, Emu XVII., pp. 63, 145 and 180; "Bird Notes from Willis Island," by Capt. J. K. Davis, Emu XXII., p. 181.

The land birds of the islands within the Barrier Reef are similar to those of the adjacent mainland. One species, however, the Torres Strait (or Nutmeg) Pigeon, *Myristicivora spilorrhoa,* roosts and nests in great number on the islands, from which it visits the scrubs of the mainland every day to feed.

The special ornithological interest of the Barrier Reef lies in the enormous colonies of tropical sea-birds which congregate to breed on some of the outer coral islands and banks. These are as follows:—

1. Wedge-tailed Shearwater (*Puffinus pacificus*), breeding on Raine Island, Willis Island, and the Capricorn Group.
2. Booby or Brown Gannet (*Sula leucogaster*), breeding on Booby Island, Bramble Cay, Ashmore Banks, Raine Island, and Willis Island.
3. Masked Gannet (*Sula dactylatra*), breeding on Raine Island and Willis Island.
4. Red-footed Gannet (*Sula piscator*), breeding on Raine Island.

5. Lesser Frigate-bird (*Fregata ariel*), breeding on Raine Island.
6. Red-tailed Tropic-bird (*Phæthon rubricaudus*), breeding on Raine Island.
7. Noddy Tern (*Anous stolidus*), breeding on Bramble Cay, Raine Island, Howick Island, Upolu Reef, Oyster Cay, and Willis Island.
8. White-capped Noddy (*Anous minutus*), breeding on Quoin Island and the Capricorn Group.
9. Wideawake or Sooty Tern (*Sterna fuscata*), breeding on Booby Island, Bramble Cay, Raine Island, Upolu Reef, Oyster Cay, and Willis Island.
10. Brown-winged Tern (*Sterna anætheta*), breeding on a great number of islands from Torres Strait to the Capricorn Group.

Several other species of birds often associate with the foregoing, including the Caspian Tern (*Hydroprogne caspia*), Crested Tern (*Sterna bergii*), Lesser Crested Tern (*Sterna bengalensis*), Black-naped Tern (*Sterna sumatrana*), Roseate Tern (*Sterna dougalli*), Little Tern (*Sterna albifrons*), and Silver Gull (*Larus novæhollandiæ*), but these are found on the coast throughout the year, whilst the ten species mentioned above disperse over the oceans except during the breeding season.

In other parts of the world colonies of sea-birds are recognised as a national asset. Under the rule of the Incas, the birds breeding on the islands off the coast of Peru were rigidly protected, and guano was collected from the islands at seasons when the birds were absent in order that they might not be disturbed. In recent years the Peruvian Government has again taken steps to give proper protection to sea-birds in the interests of the guano industry. The guano industry is also valuable on the islands off the coast of South Africa, where it is controlled by the Government. In the same country the eggs of the Jackass Penguin are collected by employees of the Government up to a certain date, after which the birds are allowed to breed without further molestation.

On the islands of Bass Strait a considerable population is almost entirely dependent on the Mutton Bird (*Puffinus tenuirostris*), the eggs and young of which have been collected during the breeding season for about one hundred years. The industry is regulated by the Victorian and Tasmanian Governments.

Though sea-birds, except cormorants, are totally protected birds under the Queensland Animals and Birds Act, no attempt seems to be made to enforce the Act, and what might be important assets (eggs and guano) if properly controlled, are entirely neglected. That protection of the more important breeding colonies is urgently required is indicated by the following quotations:—

Mosely, writing of Booby Island in 1874 ("Naturalist on the 'Challenger,'" p. 363) stated:—"The greater part of the rock is white with dung of sea-birds (the 'Booby' and the 'Wideawake') which frequent it in vast numbers."

Mr. Hedley and Prof. Richards, in their recent paper on this island, state that the birds have now entirely deserted it.

McLennan wrote in 1911 (Emu XIII., p. 148):—"When at Darnley Island we heard that the natives and South Sea Islanders from there and from Murray Island were in the habit of paying weekly visits to Bramble Cay for the purpose of getting eggs and birds for food during the breeding season, and that they brought them away in boat-loads; also that a cutter had set out for Raine Island about the same time as ourselves, but had to put back on account of bad weather, and that three boats had just left Murray Island for Raine Island. At Bramble Cay I found only two nests of the Brown Gannet containing two eggs, and three containing one egg, five nests with one young bird in each, and dozens of nests from which eggs had been taken. I also saw a great pile of skins near a heap of ashes, where the blacks had been having a feast."

Writing of an islet in the Howick Group visited by him in 1910, Dr. Macgillivray stated (Emu X., p. 219):—"At the other end was an old pelican's nesting-place, where there had been forty or more nests three or four months previously; they had evidently been deserted, as there was one or a pair of rotten eggs in nearly every nest, all limy and weather worn. I heard afterwards that a boat's crew had visited the island in June and taken a lot of eggs from it."

Dr. Macgillivray on the same journey also wrote (l.c., p. 220):—"We pass several of the Claremont Group, and call at No. 5, but see a cutter leaving it and the dry grass on the island on fire. When we come abreast the island is burning fiercely, and the birds hovering over it, uttering cries of distress. Beche-de-mer and pearl fishers (mostly the former) visit all these islands that sea-birds are known to breed upon to gather bird and turtle eggs as food for their blacks, as it saves them a good deal in the cost of keeping them."

Campbell and White, writing of the birds of the Capricorn Group wrote (Emu X., p. 201):—"The cats introduced on the North-West Island are responsible for great havoc amongst these birds of peaceful disposition."

For the proper regulation of an industry dependent on sea-birds it is obvious that information as to the approximate numbers of each species breeding on each island and as to the breeding season of each colony should be forthcoming.

It is clear that a visit to an island for a few hours or a few days is of little value for this purpose. Capt. Davis made observations over six months on Willis Island, and succeeding meteorological observers have carried on the records for two further seasons. This island has thus become an ornithological as well as a meteorological observatory. The results already obtained are of considerable scientific interest. It might be supposed that tropical sea-birds inhabiting a comparatively uniform environment little affected by seasonal changes would either breed throughout the year or at a fixed season. The observations indicate, however, that there are two breeding seasons on the island approximately six months apart and that the exact period of these breeding seasons fluctuates considerably owing to unknown causes.

That this phenomenon is not confined to Willis Island is suggested by the fact that during the Ornithologists Union's visit to the Capricorn Group in October, 1910, the White-capped Noddies on North-West Island showed no signs of laying, whilst birds of the same species were laying in hundreds on Masthead Island, only 15 miles away.

Systematic observations undertaken at several islands on different parts of the coast and carried on for several seasons, if correlated with physical and meteorological data, might well yield results of great interest to biologists and of importance from the economic aspect. By marking many birds with numbered rings it should be possible to obtain valuable information as to the life-histories of the various species. Australian ornithologists hope, therefore, that the Great Barrier Reef Committee will include the systematic study of the bird-life of the reef in its programme of research.

THE PINNACLE- OR MUSHROOM-SHAPED CORAL GROWTHS IN CONNECTION WITH THE REEFS OF THE OUTER BARRIER.

By W. E. J. PARADICE, M.B., Ch.M., Surgeon Lieutenant, R.A.N.

(Plates VI., VII., four Diagrams, nine Sections.)

No. 6.

Whilst working on that portion of the Great Barrier Reef which lies between latitudes 17 degrees and 18 degrees south, I noticed that the reefs of the outer or most easterly series tended to be crescentic in shape, having the convexity of the crescent pointing to the east (*i.e.,* out to sea).

These reefs are completely submerged at high tide and in calm weather the surface of the sea gives no indication of their existence. At the average low tide the crescentic dead summit of the reef is just awash and scattered about on this crescent are somewhat spherical masses of coral up to 4 ft. in diameter.

The majority of these masses consist of growing coral of astrean type, but others are masses of dead coral, similar in appearance to the dead coral of the reef.

At low-water springs not only do these masses of coral project out of water, but the whole crescentic summit of the reef is 2 ft. or 3 ft. above the surface of the sea, and under these conditions the beautiful growing corals of the outer edge are exposed to the atmosphere for several hours.

As one walks from the centre of the crescent towards its horns or into the concavity, the continuity of the flat surface of dead coral becomes interrupted by holes or basins in which growing corals thrive. As we go further, the dead surface begins to dip and from it small pinnacles of coral grow up to the surface. Continuing further still, the general surface of the reef becomes deeper and deeper, and pinnacles of growing coral continue to be met with, each one rising from a greater depth than the former (*See* diagram 1).

I have referred to that portion of the reef in which pinnacles and basins occur as the "Zone of Irregular Growth," and in this zone the level of the surface of the reef, from which the pinnacles rise and into which the basins sink, gradually dips from sea level to about 10 fathoms.

Outside this zone, *i.e.,* in water deeper than 10 fathoms, the basins are absent, the pinnacles rising from a smooth bottom.

I have noticed that when it is possible to see the bottom between the pinnacles in deep water, it is usually of coral sand, with small clumps of dead or growing coral projecting here and there (*See* Diagram 2).

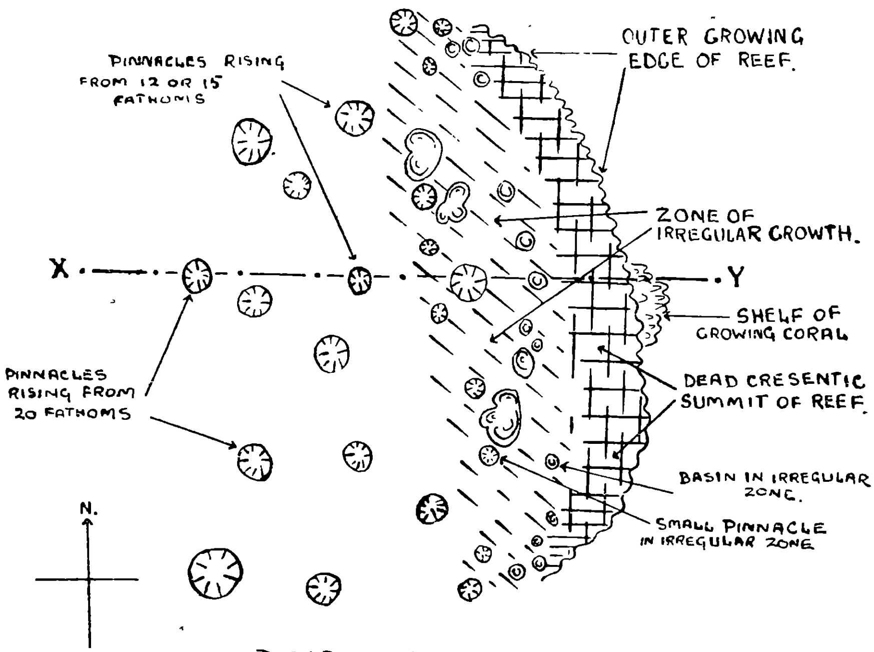


DIAGRAM. I. W.E.J.P.

DIAGRAMMATIC REPRESENTATION OF THE PLAN OF A TYPICAL REEF.

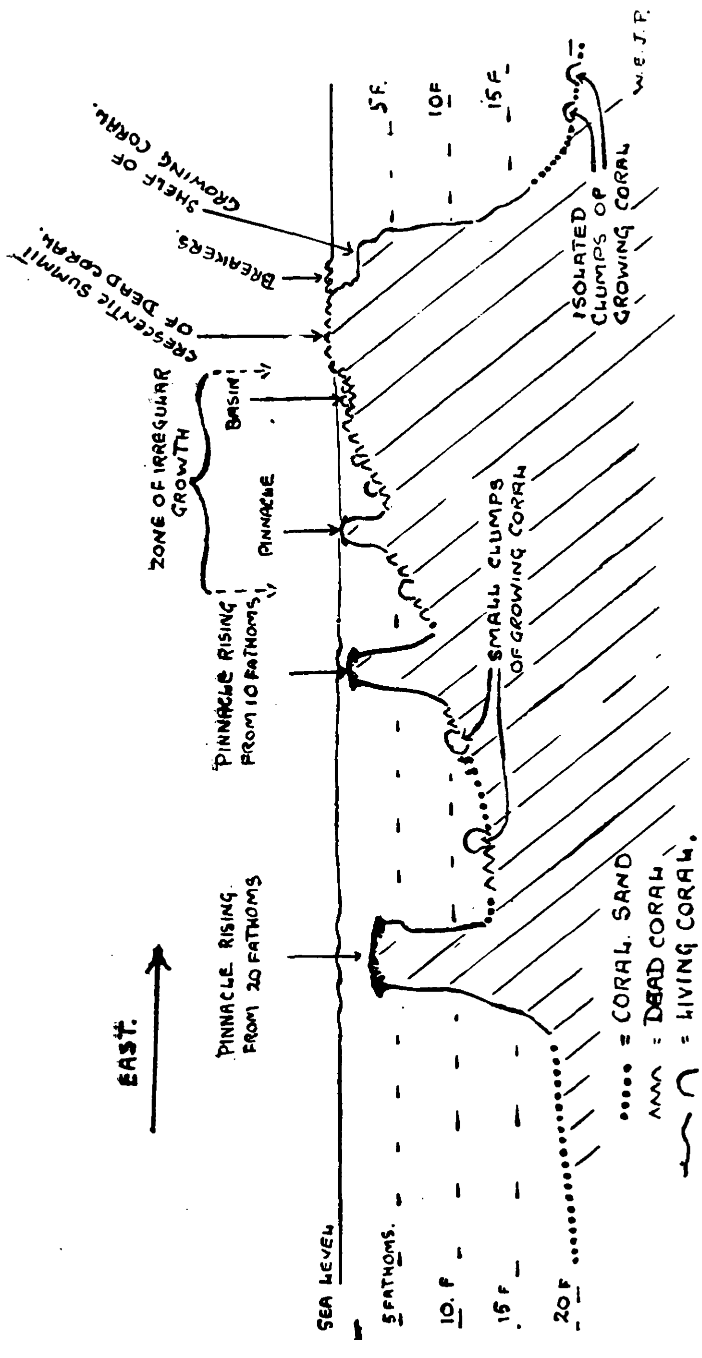


DIAGRAM. 2.

VERTICAL SECTION. EAST AND WEST THROUGH A TYPICAL REEF SUCH AS WOULD BE OBTAINED ALONG LINE XY OF DIAGRAM. I.

On the seaward edge of the reef the coral is all growing, and in places it descends almost vertically to the bottom, which may be anything up to 20 or 25 fathoms.

In some places along the outer edge of the reef we meet with a shelf of growing coral which projects outwards at a depth of 2 or 3 fathoms and then drops steeply.

The bottom of the deep water to seaward of the reef consists of coral sand with isolated clumps of dead or growing coral, and in some rare cases there are pinnacles rising from the bottom to seaward of the main reef.

In Diagram 2 the shelf which is met with in places is shown, and the largest pinnacle is shown to end some fathoms below the surface. This is often the case, but in as many cases the pinnacle just reaches the surface.

A Suggested Explanation to Account for the Form Assumed by these Outer Reefs.

The long axis of each reef runs in a more or less north and south direction.

There are two factors which may have some bearing on this:—

(1.) The physical features of the mainland and the elevations and depressions of the sea bottom all run parallel to one another in a direction which is somewhat north and south. By looking at a series of vertical sections through the outer portion of the Barrier we note that there is a gutter about 40 fathoms deep that runs parallel to the 100-fathom line at about 3 miles distance. Outside this gutter there is a ridge which rises to within 20 or 30 fathoms of the surface and then from this ridge the bottom falls away, becoming deeper and deeper as we go eastward.

May it not be that these reefs have as a foundation ridges which run in this given direction?

(2.) The current along the outer Barrier run south (it has been noticed that in running east and west lines of soundings the ship is carried to the south).

May not the continued action of this current cause the line of growth to extend in its direction from the initial growing point?

As to the crescent form of the reef:—

Having a reef growing in a north and south direction it will be acted upon by the constant swell of the Pacific coming in from the east and breaking on it.

May not this action tend to carry the growing ends of the reef with it in a westerly direction? And may it not tend to stop growth in an easterly direction, giving the steep eastern edge of the reef by breaking away fragile coral and causing a compact form of growth? At the same time that it interferes with the outwards growth of the reef as a whole, by bringing food and oxygenating the water, it would tend to make the individual polyps grow, and in many generations the process of adaptability would assert itself and the polyps would form a compact wall of healthy growing coral to the east rather than a series of thin shelves which could be broken away by the sea.

As to the irregular growth in the concavity, and the pinnacles of coral:—

As the reef grows the sea would wash broken pieces of coral from the crest over into the still and sheltered water to the west. Some of these pieces would die and in time would act as a nucleus for other polyps to grow upon.

Other pieces would probably begin to grow in their new situation and thus would an irregular growth start.

Near the reef the growing foci would be close to one another, and in time would form a solid coral growth with perhaps a hole here and there such as the basins mentioned.

Further to the west they would be more scattered, and these in time would give the pinnacles.

The water in which these pinnacles grow is far enough from the sheltering reef to be affected by currents, and therefore oxygenated and food-bearing, and thus is able to cause prolific coral growth.

The action of the breakers is absent from this area and therefore the coral is able to grow without impediment in any direction, the result being pinnacles almost circular in cross section.

On approaching the pinnacle we note that the top consists of circular shelves (above line $A B$ in Diagrams 3 and 4), but below these shelves one can only see the clear blue water.

There is such a degree of undermining that the supporting pillar cannot be seen.

I think that these pinnacles have grown to the surface by a series of shelves.

The final condition may be as in Diagram 3.

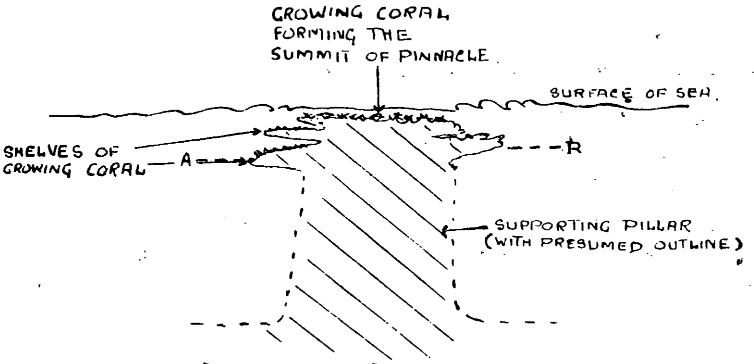


DIAGRAM. 3.

SECTION OF A PINNACLE RISING FROM DEEP WATER.

DIAGRAM. 4.

SECTION OF PINNACLE TO SHOW ANOTHER POSSIBLE FORM OF SUPPORTING PILLAR

IN DIAGRAMS 3 AND 4. EVERYTHING ABOVE LINE AB IS VISIBLE, EVERYTHING BELOW IS HYPOTHETICAL.

In this case I suggest that the absence of light may cause the coral of the lower shelves to die as the new shelves have grown out and cut off the light supply.

We know that dead coral tends to lose its irregularities, and under these circumstances we would expect a cylindrical supporting pillar, the lower shelves having disappeared so that nothing can be seen below the upper living shelves.

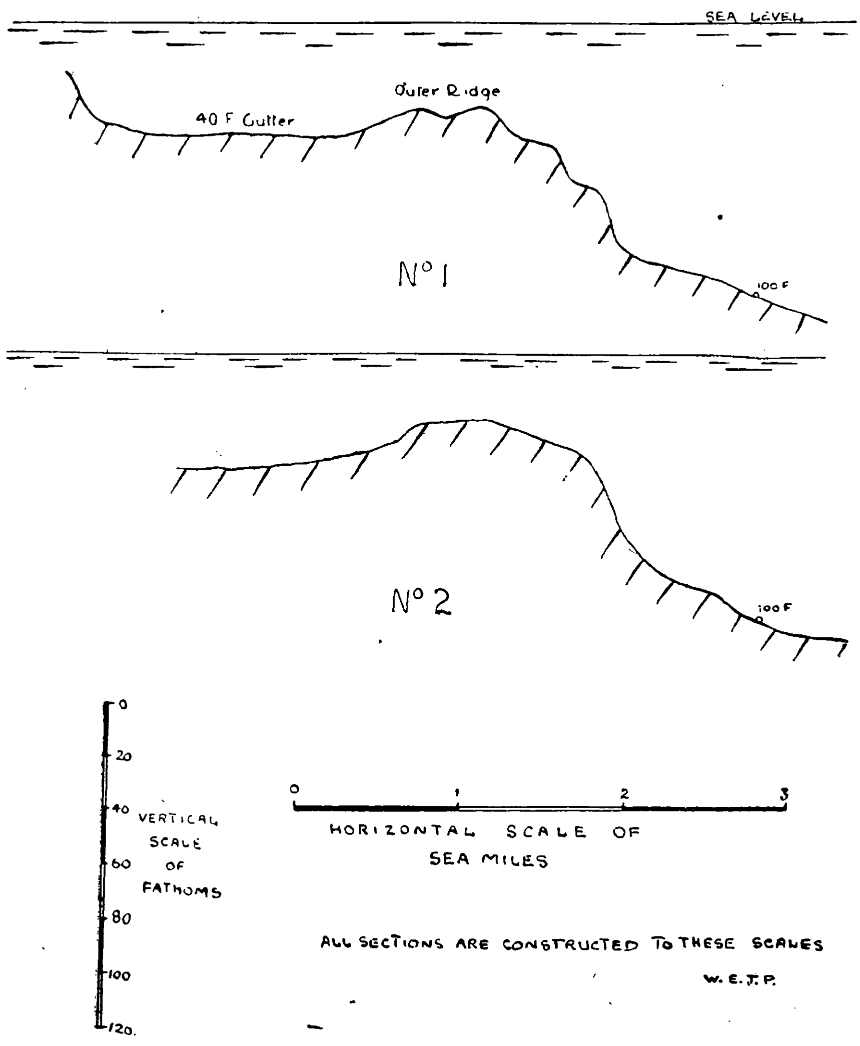
If by any chance the coral in the lower shelves lives, each shelf, as it grows above its forerunner, must be appreciably greater in diameter than that shelf, and thus the pillar would be hidden from view and the section would be as shown in Diagram 4.

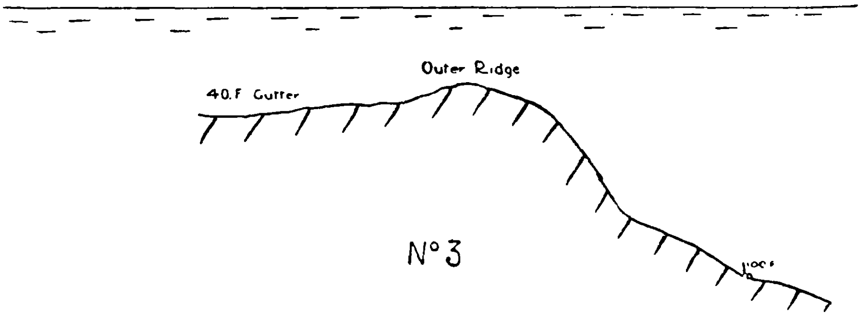
NOTE.—The Sections No. 1 to No. 8 run east and west. No. 1 is along latitude 17 deg. 7 min. south. No. 8, which is on a line passing through Flora and Coates Reefs, is along 17 deg. 11½ min. south, and the others are fairly evenly spaced between these two.

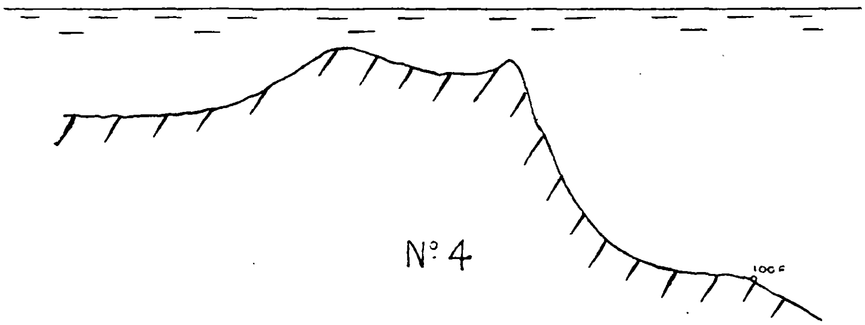
No. 8A.—This is a complete section of which the eastern extremity has been reproduced, as No. 8. (*See* separate diagram.)

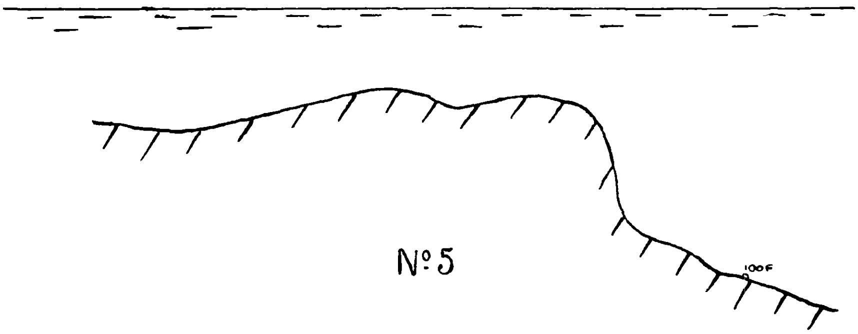
It is noticeable in this section that reef patches which are a growing coral formation have their highest portion to the east.

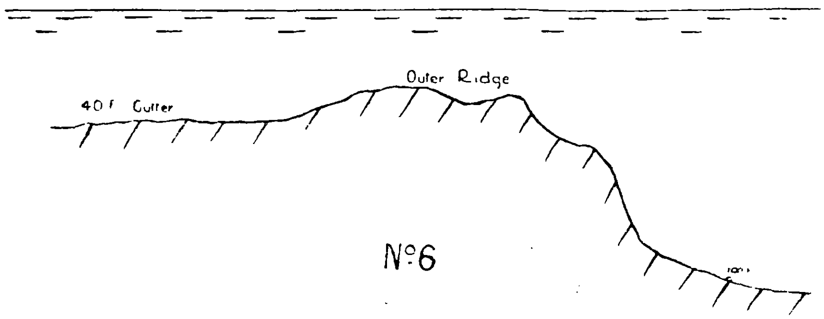
It appears that here we have a reef growing towards the surface, and, being influenced by the factors mentioned in this paper, is behaving in the manner that has been suggested as the probable manner of growth of a typical reef of the other Barrier.

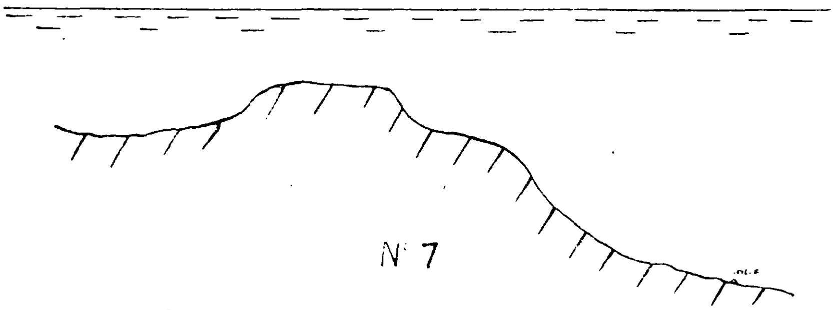


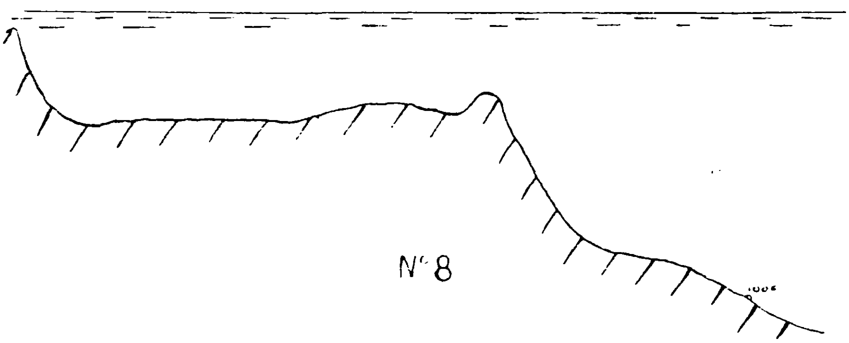

Outer Ridge
40.F Gutter
N° 3


100 F
N° 4


100 F
N° 5


Outer Ridge
40 f Gutter
N°6


N° 7


N° 8

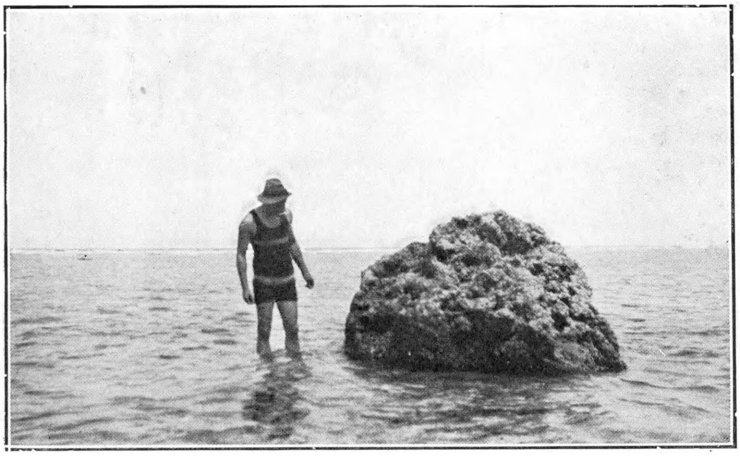


Photo. of a "Niggerhead" or Mass of Dead Coral Resting on the Dead Summit of a Reef.

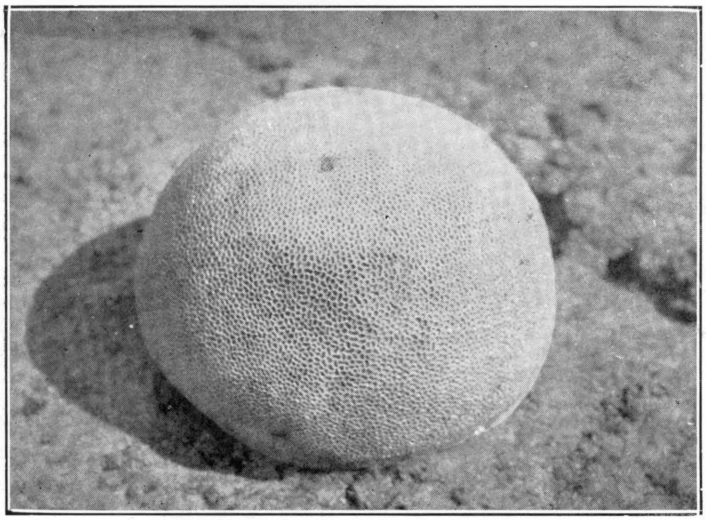


Photo. of a Large Growing Brain Coral on the Dead Summit of a Reef.

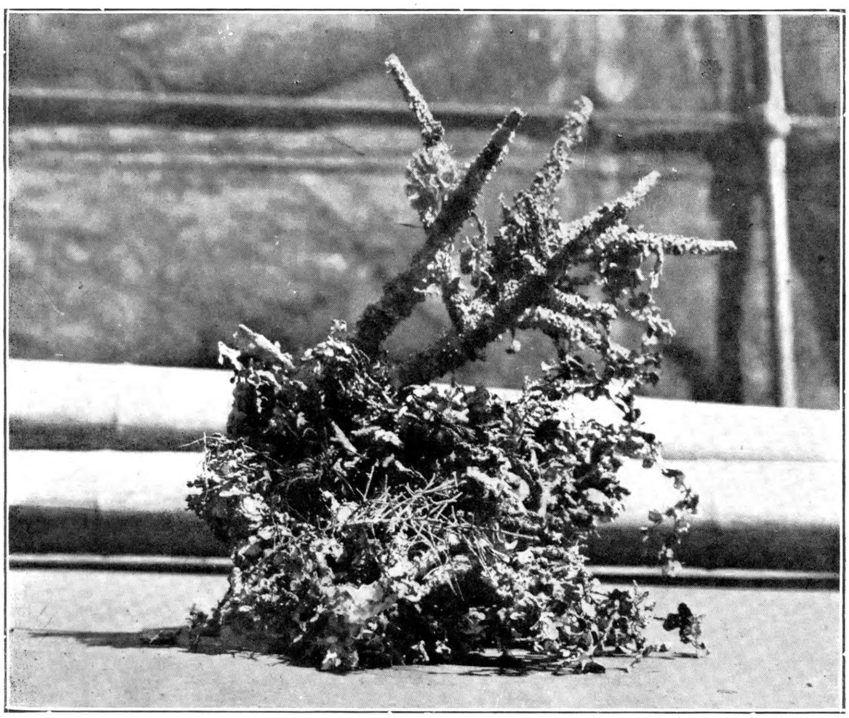
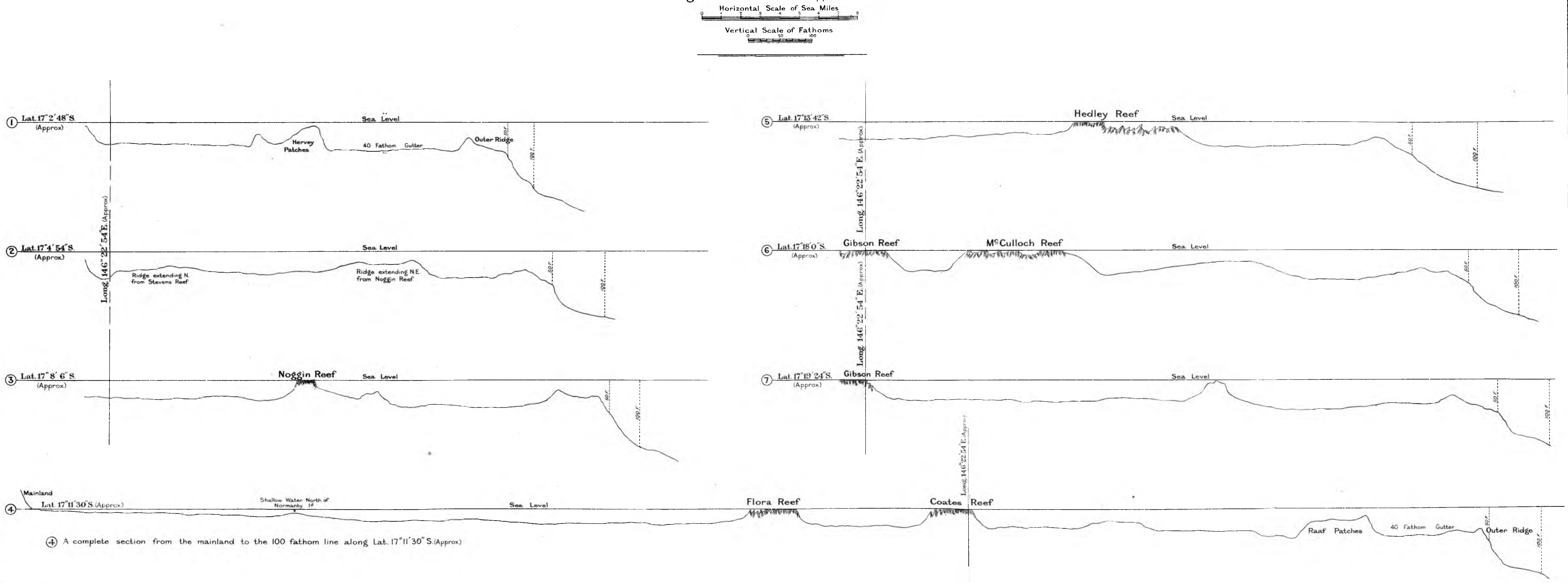


Photo. of a Piece of Dead Coral dredged from a Sandy Bottom at 20 Fathoms, showing how it has acted as a Nucleus for Marine Growth.

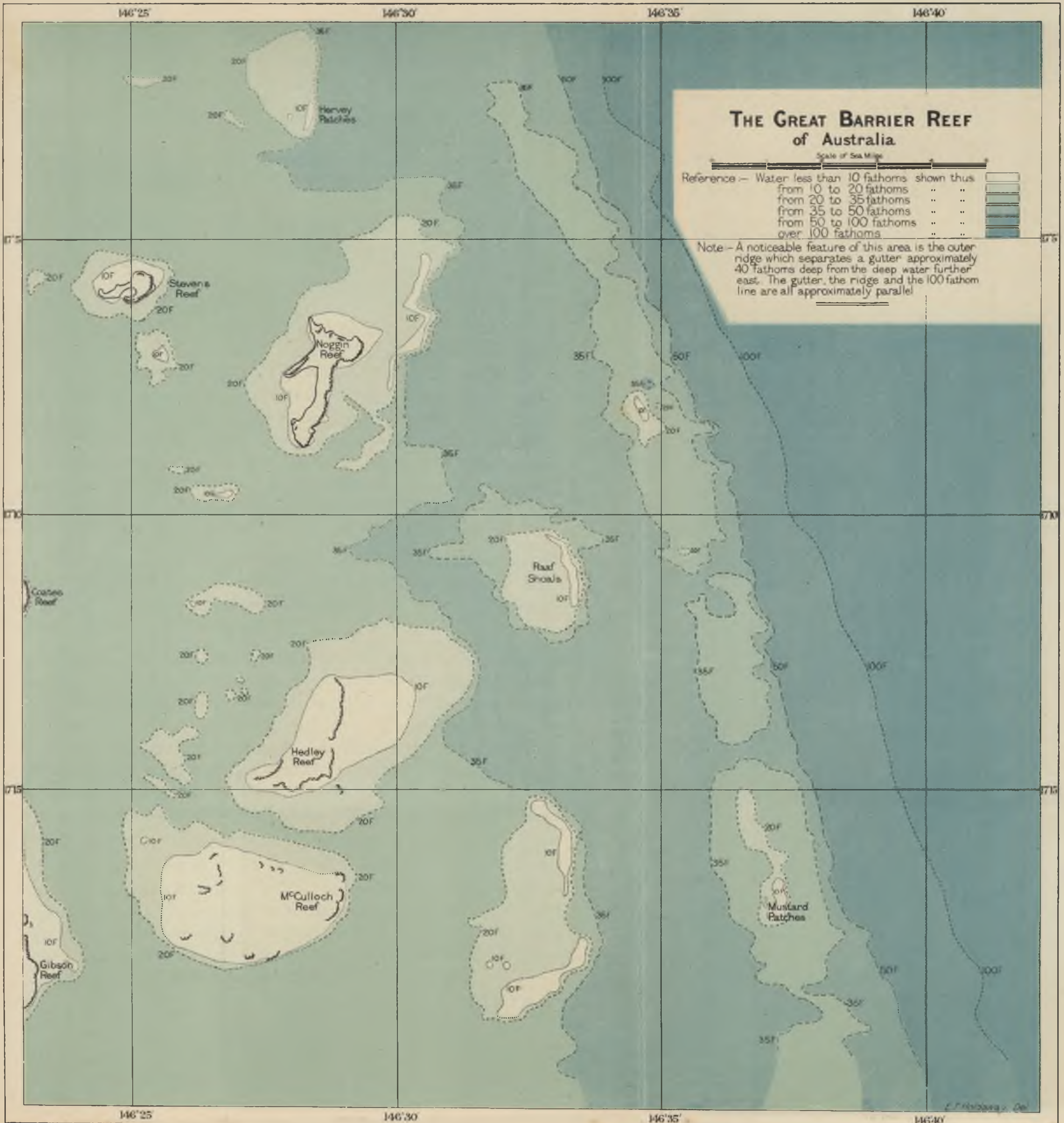
Face page 60.]

The Great Barrier Reef of Australia

Sections from Longitude 146° 22′ 54″ E. (Approx.) to the 100 Fathom Line.



④ A complete section from the mainland to the 100 fathom line along Lat. 17° 11′ 30″ S. (Approx)


THE GREAT BARRIER REEF
of Australia
Scale of Sea Miles
Reference :— Water less than 10 fathoms shown thus
from 10 to 20 fathoms .. ..
from 20 to 35 fathoms .. ..
from 35 to 50 fathoms .. ..
from 50 to 100 fathoms .. ..
over 100 fathoms .. ..
Note – A noticeable feature of this area is the outer ridge which separates a gutter approximately 40 fathoms deep from the deep water further east. The gutter, the ridge and the 100 fathom line are all approximately parallel
146°25′
146°30′
146°35′
146°40′
Hervey Patches
Stevens Reef
Noggin Reef
Raaf Shoals
Coates Reef
Hedley Reef
McCulloch Reef
Gibson Reef
Mustard Patches
E. F. Holloway, Del.

A RAISED BEACH AT THE NORTH BARNARD ISLANDS.

By CHARLES HEDLEY, Scientific Director of the Great Barrier Reef Committee.

(Plates VIII. to X.)

No. 7.

The lighthouse on North Barnard Island, in south latitude 17° 41′ and east longitude 140° 11′, forms a conspicuous landmark for the shipping passing from Townsville to Cairns. It is erected on Kent Island, the outermost of a string of five islands composing the North Barnard Group. These are all overgrown by a dense rain-forest, and appear as tabular blocks about 300 ft. in height, parted by narrow channels. Their even summits and proximity present the row as disjointed fragments of a cape that once projected from the mainland.

The rock is hard schistose and even-grained, frequently seamed with quartz and glittering with mica. Numerous fissures, some large and developing caves, indicate how the disarticulation of the group may have been effected.

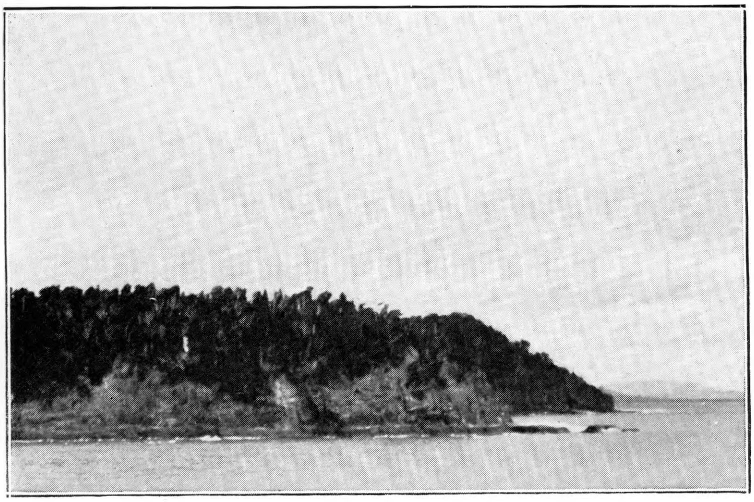
Though the steep seaward face is generally masked in forest, the precipitous descent from the lighthouse to the beach is visible even from the deck of a passing vessel. Along the base of this escarpment and best seen in the profile of the island, there runs a continuous ledge. At one point the base of the cliff is notched. This ledge can only be interpreted as an elevated beach. An index to its age is supplied by the decay of the cliff behind, and the vegetation that now clothes it proves that the cliff is still beyond surf control.

On close approach this ledge is found to be about 8 ft. above mean level, using a zone of small, thickly spread rock oysters as a datum line. The surface is rough and much weathered; it is equally devoid of terrestrial vegetation and of marine organisms. The width is irregular, for sometimes the ledge is interrupted and at others may attain a breadth of 15 yds.

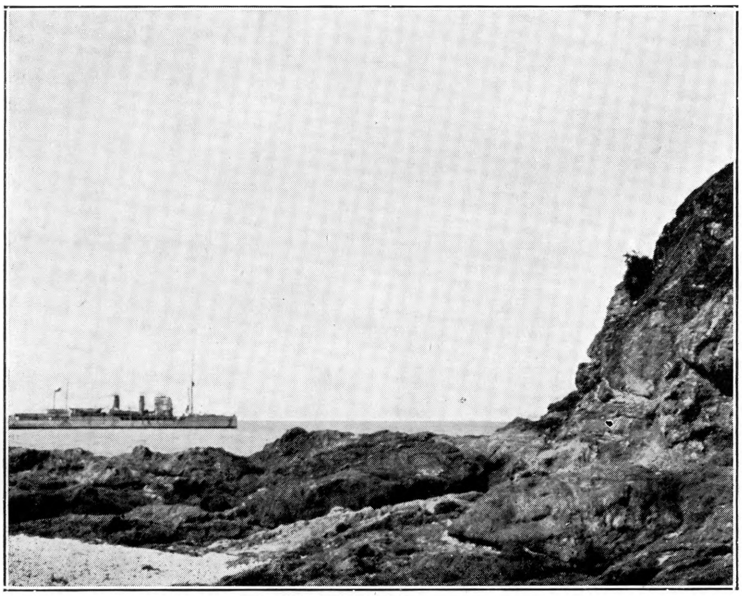
A similar platform borders the eastern side of Jesse Island, that which lies next to Kent Island, but on the west coast of Jesse the beach is reduced to the plane of present erosion and no raised platform occurs there.

Search on the Frankland Islands, 29 miles to the north, failed to discover shelves like those of the North Barnards. But the rock of these islands differs by its massive character. The seaward beach of Russell Island, for instance, is formed of gigantic porphyritic boulders and huge convex rock faces.

Perhaps where marine erosion might carve a platform upon rock of more even grain, it may fail to do so upon granitoid rock of massive character.

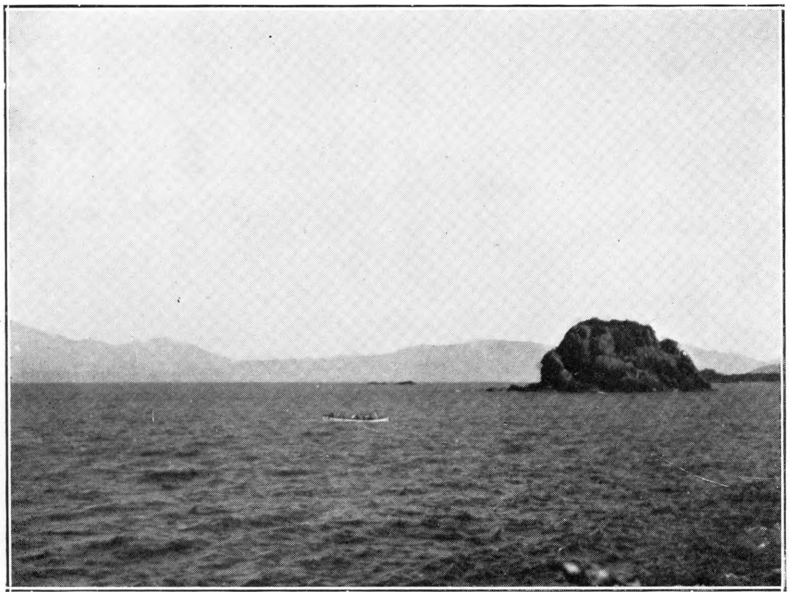


JESSE ISLAND, NORTH BARNARD, FROM ANCHORAGE TO SHOW RAISED MARGINAL LEDGE.

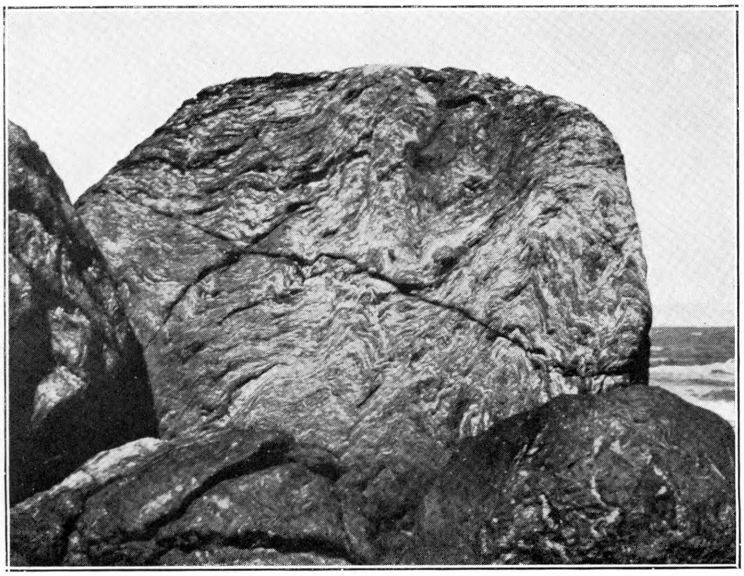


JESSE ISLAND, NORTH BARNARD, CLIFF AND RAISED LEDGE LOOKING TOWARDS THE ANCHORAGE.

Face page 62.]

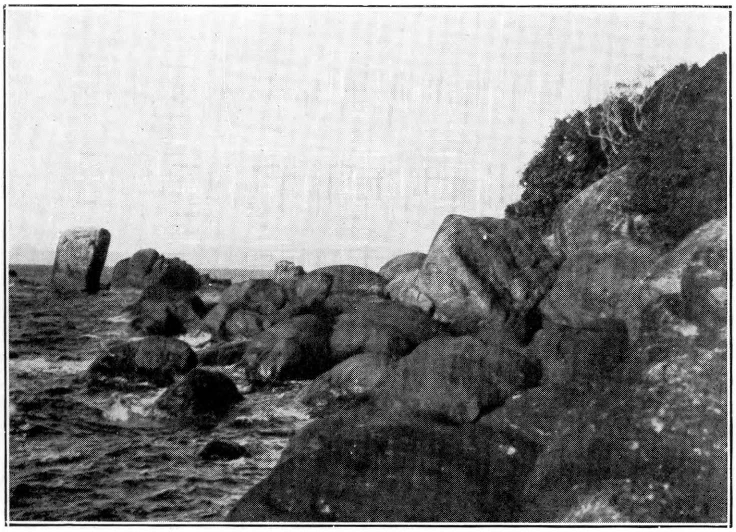


ILLUSTRATING THE STEEP SIDES AND ABSENCE OF RAISED LEDGE CHARACTERISTIC OF MASSIVE ROCK.



GIANT BOULDER OF SOUTH-WEST BEACH OF RUSSELL ISLAND.

Face page 62.]



BOULDER BEACH OF EAST COAST, RUSSELL ISLAND, FRANKLAND GROUP.

THE TOWNSVILLE PLAIN.

By CHARLES HEDLEY, Scientific Director of the Great Barrier Reef Committee.

(Plates XI. to XIII.)

No. 8.

Castle Hill, or, in the aboriginal dialect, Cudtheringa, is a picturesque hill crowned with a red cliff which rises steeply above Townsville to a height of 933 ft. The traveller who climbs this hill is rewarded with an unusually fine panorama of sea and island, of plain and mountain.

On one side Cleveland Bay extends out to Cape Cleveland and Magnetic Island. On the other a level plain stretches from 4 to 7 miles across to a semicircle of hills, 1,000 or 2,000 ft. above it. Two gaps interrupt this range; through one the southern railway enters, and through the other the northern railway leaves the plain. In the background more lofty peaks, Mount Elliot and Hinchinbrook, rise almost to 4,000 ft.

So nearly is the level of the sea continued by this plain that slight imagination is needed to prolong Cleveland Bay 5 miles further inland to Mount Stuart and to make of Castle Hill another island of this larger bay.

On the landward side the plain behaves like a lake in the way that it thrusts its arms and fingers into the valleys among the hills. On the seaward side it passes gradually into mangrove swamps, and these again to a beach of shallow sand and mudbanks. These sandbanks are now advancing seaward, for where the Admiralty Chart No. 1102 of Cleveland Bay (drawn in 1886 by the Captain and Officers of H.M.S. "Paluma") showed 3 to 6 ft. of water, outside the breakwater north of the magazine, there the beach now dries at low spring tides.

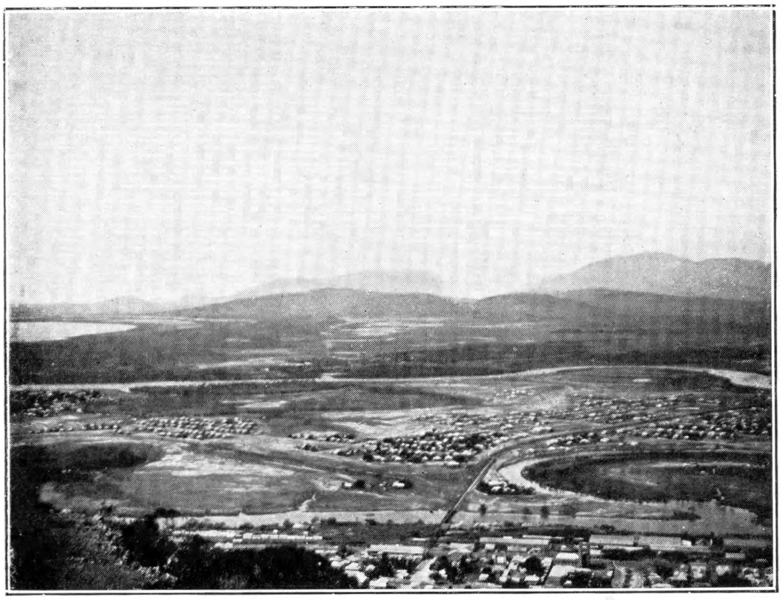
The Ross estuary continues to join that of Alligator Creek on the east, which in turn is prolonged into the saltpans and mangrove swamps which link Cape Cleveland to the mainland.

Salt water ascends the Ross River for about 10 miles to a weir. At this point, as I am informed by Mr. E. Wright, Crown Lands Ranger, the river in flood sometimes breaks away from its usual channel and runs to Rose Bay, thus reaching the sea on the opposite side of Castle Hill to the usual channel. This shows how flat is the area round Townsville and how little it would take to isolate Castle Hill from the mainland.

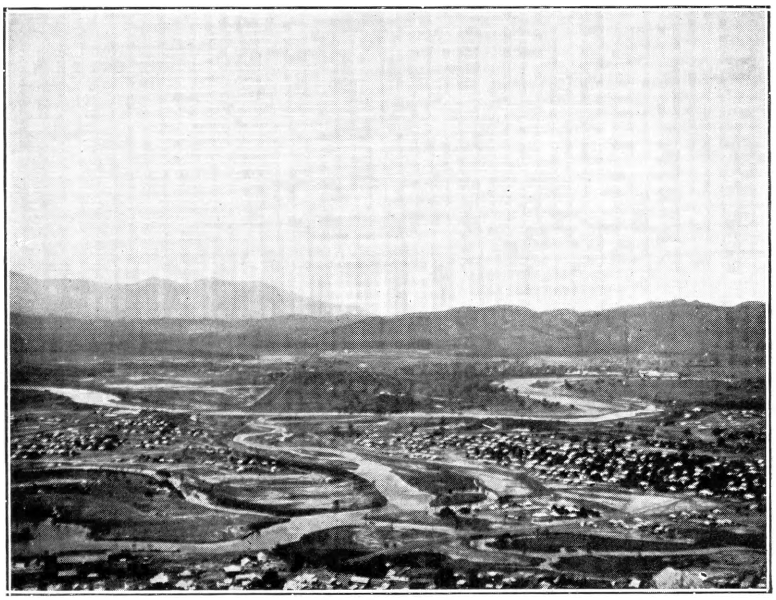
The Ross River meanders in wide loops across the plain to reach the delta head at Townsville. Here the river divides to enclose Ross Island, the site of a flourishing suburb. The whole of Ross Island is a dead level, scarcely above reach of the tide and composed of mud, such as occurs in mangrove swamps. A patch on the south of the island is still an ordinary mangrove swamp, covered at every tide and overgrown with Rhizophora and other mangrove trees. This swamp is bordered by a treeless "samphire" flat, or salt pan, only reached by unusually high tides, and from which the mangrove forest has disappeared. In its turn the samphire flat meets another higher flat, overgrown with grass and above the horizon of the spring tides. This is a perfectly level mud plain, upon which several streets have been built. Except a small area of dunes, no ground on the island is higher.

Where the samphire flat meets the grass flat, there occurs a miniature mud cliff about 2 ft. high. To me this indicates that the grass flat was once an ordinary mangrove swamp, that it was elevated by tectonic action, and that the mangrove forest withered and disappeared when the sea water drained away. Finally, that wavelets at high tide encroaching on higher ground have carved these miniature cliffs. (*See* Plate XIII.)

The flat valley through which the Ross River runs appears, when viewed from the hill top, to have the same history as Ross Island—to have been formed at water level and afterwards to have been slightly elevated. But this explanation is not supported by further inquiry. For the sides of the valley finally rise as they meet the hills. The alluvium on the seaward side of Castle Hill, as I ascertained by aneroid readings, begins at the Botanic Gardens 35 ft. above the sea. But on the opposite inland side the alluvium

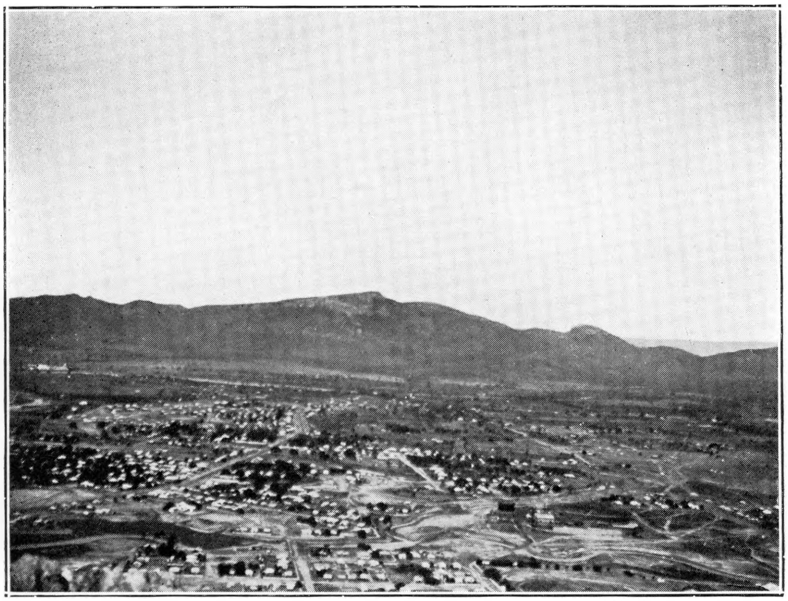


Panorama from Castle Hill, Part 1, Left; showing Cleveland Bay and Ross Island.

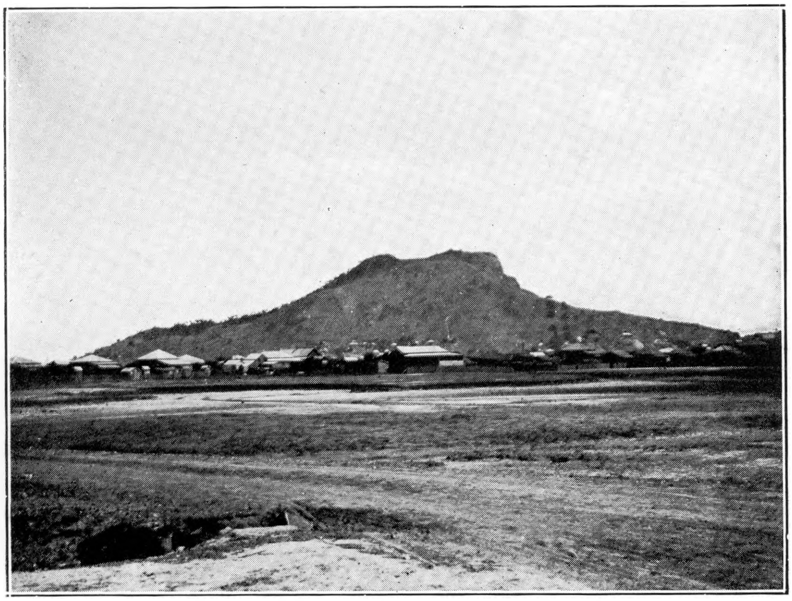


Panorama Continued, Part 2, Centre. The Ross River Meanders through the Plain and Mount Elliott Rises in the Background.

Face page 65.]



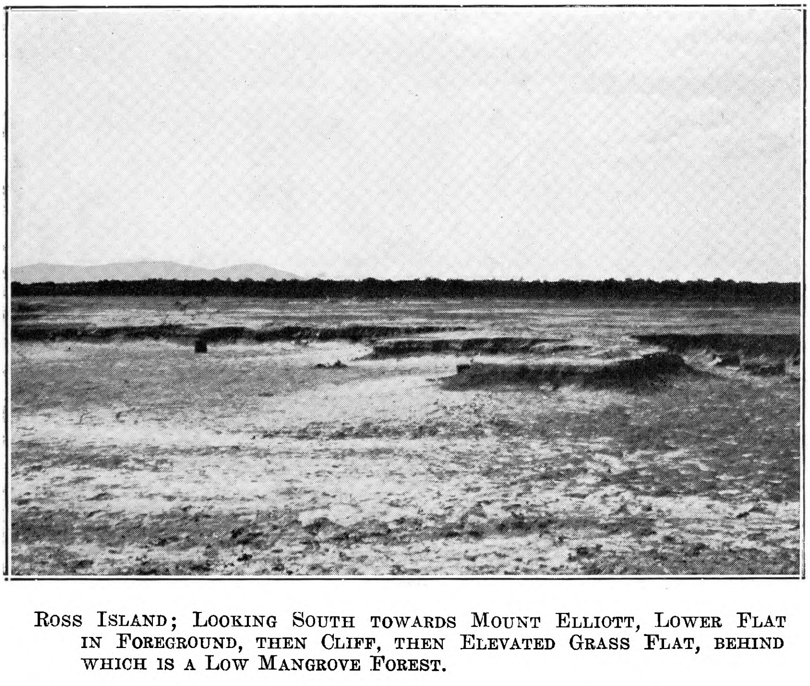
Panorama Continued, Right, Part 3. The Suburbs of Townsville, with Mount Stuart in the Background.



Castle Hill, seen from Ross Island.

Face page 65.]

ROSS ISLAND; FOREGROUND. THE LOWER FLAT, THEN MINIATURE MUD CLIFFS, BACKGROUND ELEVATED GRASS FLAT AND HOUSES.



ROSS ISLAND; LOOKING SOUTH TOWARDS MOUNT ELLIOTT, LOWER FLAT IN FOREGROUND, THEN CLIFF, THEN ELEVATED GRASS FLAT, BEHIND WHICH IS A LOW MANGROVE FOREST.

reaches as high as the Old Cemetery, 85 ft. above the sea. Had the alluvium been laid down under water the level on each side of the hill would be the same. The floor of the upper valley as it now exists is formed of the waste shed from the high ground surrounding it.

The Townsville plain represents a readjustment to a new base level consequent on a large subsidence. The latter event may date from the close of the Tertiary and must have greatly changed the landscape. The slight and recent elevation noted at Ross Island has not materially affected the structure of this plain.

When it is discovered what rocks at what depth underlie the Townsville plain, our knowledge of the evolution of the coast should take a long step forward. The granite hills that rise abruptly and enclose the plain suggest that granite continues underneath from hill to hill. But the exposed granite may be the denuded cores of fold mountains, whose crust may be preserved still in synclinal troughs under the recent alluvium.

The impressive contrast between the harsh granite towers and the smooth alluvial carpet speaks of different cycles, of geological storm and calm. Turning from the past to the future, what forecast is there whether the earth movements so energetically performed in the ante-penultimate cycle will continue, augment, decrease, or cease? It is suggested that these movements originate in the sinking of the floor of the Carpenter Deep. For its area this deep is already profound. If that depth has now reached equilibrium, a period of stability for the shore may be due. But if the Carpenter Deep shall continue to sink from great to greater depths, then the coast may be racked to correspond. Alteration of levels of land and sea have produced, as is argued above, recent changes in the shore line. It is now deduced that such alterations must have effected corresponding changes in the reefs of the Great Barrier.

CORAL SHINGLE AS A BEACH FORMATION.

By Charles Hedley, Scientific Director of the Great Barrier Reef Committee.

(Plates XIV. and XV.)

No. 9.

Coral shingle, as a constituent of beach formation, behaves quite differently from sand or ordinary rock shingle. So far as my recollection goes, this fact has been insufficiently discussed in literature.

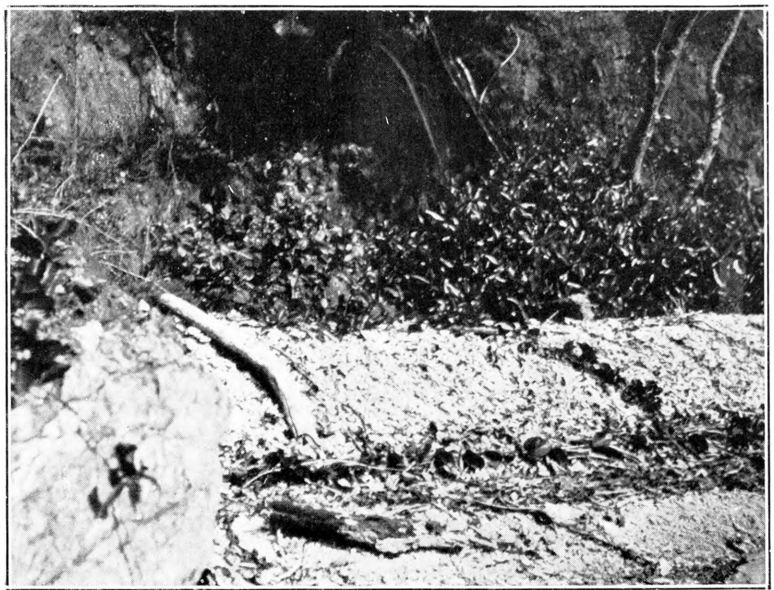
Where surf reaches a beach after traversing a reef of growing coral, it sweeps together a bank of coral shingle. This shingle consists of fragments of coral, broken lengths of staghorn—Acropora and Pocillopora—interspersed with odd Fungia and pieces of the more massive brain or astrean corals.

Predominance of branching coral gives the resulting beach a peculiar composition; instead of the round pebbles which form on ordinary shingle, this beach is built of crooked coral sticks, 3 or 4 in. long. These are laid lengthwise in the direction of the waves which deposit them, and have a tendency to interlock. Such action both stiffens the mass and holds the individual fragments apart. In this respect the coral shingle is comparable rather to a stack of driftwood than to a pile of ordinary pebbles.

Another distinction between the two types of beaches lies in the difference in weight of stone and coral. Where both occur together on a beach the waves exercise a selection, sorting the rock pebbles for the foundation and sifting the coral to make a pure superstruction. The extreme lightness of the coral has other expressions. Fragments are tossed high and easily redistributed by any change of weather. Here is the cause of the extraordinary height and steepness of coral beaches, so frequently remarked by travellers. Partly from lightness and partly from interlocking of particles, the coral beach tends to produce a succession of sharp crests.

If removed from disturbance the pile will collapse at last into a bulk unexpectedly small. Coral shingle cast on the beach for many years acquires a coal-black crust which misleads inexperienced observers to mistake it for some other substance.

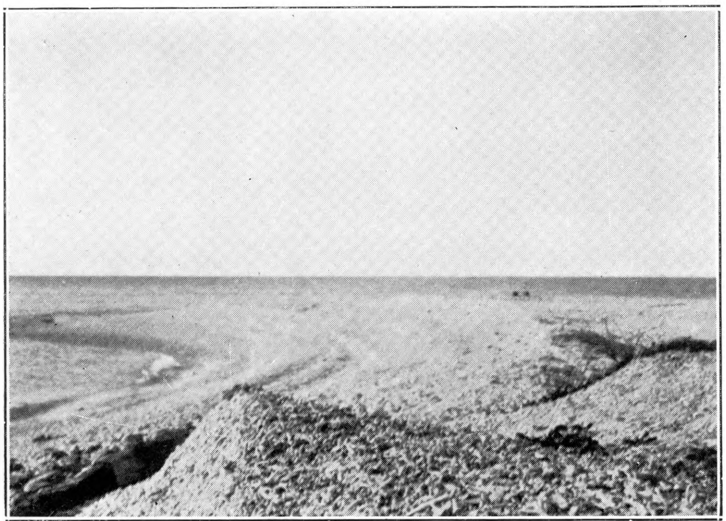
CORAL SHINGLE BANK AT JESSE ISLAND, NORTH BARNARDS, SHOWING INTERLOCKING OF FRAGMENTS AND STEEP SLOPE, AUGUST, 1924.



JESSE ISLAND, NORTH BARNARDS. FRAGMENT, BLACK WITH AGE, OF HURRICANE BEACH, OVERGROWN ABOVE WITH SHRUB (SCÆVOLA) AND BELOW WITH CREEPER (IPOMÆA).

Face page 66.]

BEACH OF RUSSELL ISLAND. COMPOSED OF CORAL SHINGLE, SIFTED PURE, LYING ON STRATUM OF ROCK BOULDERS.



CORAL SHINGLE, KENT ISLAND, NORTH BARNARD GROUP.

[*Face page* 66.]

AN OPACITY METER.

By CHARLES HEDLEY, Scientific Director of the Great Barrier Reef Committee.

(Plate XVI.)

No. 10.

Distribution of reef corals and their associates is controlled by two factors, temperature and sediment. In the Barrier Reef area temperature steadily increases from south to north and sediment from east to west.

Though we have gathered some scanty data on the sea temperature of this region, the other factor remains unstudied, neither has any method or instrument been suggested here for obtaining information on this subject.

As a first step in this direction, I assumed that matter in suspense in the sea would vary in proportion as the water progressively changed from translucency to opacity, and devised a simple gauge to measure the latter. During my stay on board H.M.A.S. "Geranium," Commander Bennett kindly gave his guest the benefit of his advice and experience in making and operating this tool.

From my design the meter, as shown in Plate XVI., was made by an engineer on board. This consists of a truncated cone 13 in. in major diameter (chosen as being one-third of a metre) 7¾ in. deep, with a central orifice 2½ in. in diameter at the small end. The cone is constructed of sheet iron, fastened by four rivets on an inch overlap, it weighs 3 lb. 12 oz., and is painted dead white. It is fastened on a bridle of three strings, inserted in equidistant perforations near the rim. At 2 ft. 6 in., the bridle strings are gathered to a swivel link which is made fast to a sounding line marked in fathoms.

The meter is used with the small end of the cone downwards, the orifice allowing an easy passage through the water. It is lowered to vanishing point and at the critical position is raised and lowered once or twice to verify the observation and the depth is read from marks on the sounding line.

Probably the most exact reading, and the attainment of a greater depth, would be reached by lowering the cone from a boat and making the observation of the depth at which the white disk is lost to sight, by the aid of a water telescope. Actually, for want of opportunity the readings here noted were made from the rail of the ship.

Probably neither end of the scale from transparency to opacity is here registered. As would be anticipated, transparency regularly increases with the distance from the land. Probably the conformation of the reef confines the heavily charged river water to the coastwise channel and clear water occurs nearer than usual to a continent.

At the jetty at Townsville, where the water is extremely muddy, the disk vanished at a depth of 6 ft. Our maximum reading of 109 ft. was made at Coates Reef, 24 miles from the land. Intermediate records are:—Jetty at Thursday Island, 7 ft.; jetty at Cairns, 8 ft.; off Pipon Lighthouse, 2½ miles from Cape Melville, 17 ft.; three islands in Torres Strait, within the influence of the Fly River, Coconut Island, 18 ft.; Bramble Cay, 22 ft., and Darnley Island, 30 ft.; Kent Island, North Barnard Group, 3 miles from shore, 33 ft.; Russell Island of the Frankland Group, 7 miles from the coast, 39 ft.; and Peart Reef, 19 miles from the land, where the depth registered was 66 ft.

AN OPACITY METER.

Face page 68.]

A DISUSED RIVER MOUTH AT CAIRNS.

By CHARLES HEDLEY.

(Plate XVII. and one Text Figure.)

No. 11.

Stretching north and south from the wharf at Cairns is a broad and deep salt-water channel. On either bank extensive mud flats overgrown with mangroves border this fine sheet of water. The town of Cairns is built on one of these estuarine flats. Further upstream the channel branches and a large mud island is embraced in the delta. It would be natural for a traveller when he entered this channel, Trinity Inlet, to imagine that he was ascending one of the larger rivers of the continent. But he would be astonished to find so large a delta, filled with silt accumulated for ages, ending at a short distance in a trivial watercourse.

A little to the north of Cairns, the Barron River is vigorously projecting its delta into Trinity Bay. It is noteworthy that the riverless estuary at Cairns contains a greater mass of alluvium than the powerful Barron has yet deposited.

Running south from Cairns is a wide, straight, trench-like valley, walled in by mountains from two to three thousand feet high, which plunge steeply and end abruptly at the margin of the valley. The floor is a broad sheet of the richest alluvial and is mostly occupied with sugar plantations. If the alluvial is as deep as the hill slopes suggest, the rock bottom may well be far below sea level. Structurally this valley is comparable to the Hinchinbrook Channel, and both may indicate important strike valleys. A river, the mouth of which is now represented by Trinity Inlet, may, as W. H. Bryan has suggested to me, have been continued through what is now Trinity Bay to the Trinity Opening in the Great Barrier Reef.

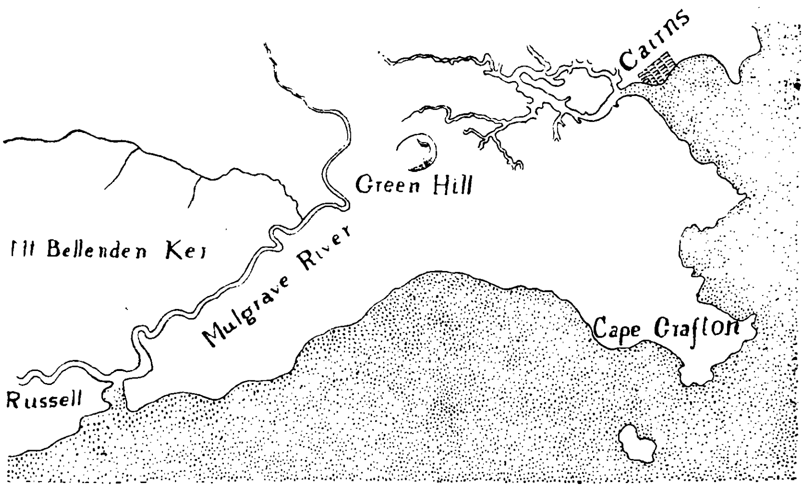
The block of coast between Cairns and the Barnard Island, with a straight edge ending in a T head, has some resemblance to a block of the New South Wales coast, between Trial Bay and Port Stephens, described by Woolnough (Woolnough in Hedley Proc. Linn. Soc. N.S.W. XXXVI., 1911, p. 31). A feature on which that geologist dwelt was the former existence of a large marginal stream now replaced by several smaller radial rivers.

The Mulgrave River enters this great trench valley, turns at right angles, and runs south. Running northwards along the same valley the Russell River meets the Mulgrave at Constantine Bay, about fifteen miles from Cairns, where the two rivers go out to sea together. Their combined estuary is a structure curiously inadequate to the capacity of such strong streams. Had they been working for long at Constantine Bay, a considerable projection from the coast should have resulted.

Comparison between the deltas of the Barron, Cairns Harbour, and the Russell River affords evidence that a large river, which has disappeared, recently and for a long time poured its waters through Trinity Inlet to Trinity Bay.

A theory here advanced is that it was the Mulgrave River which formerly flowed into Cairns Harbour, further that the Russell River then continued along the trench valley to join the Mulgrave and so escape through the same estuary; perhaps at that period the Upper Johnstone also drained into the Russell.

Long ago Dr. R. L. Jack (Jack and Etheridge: Geology and Palæontology of Queensland and New Guinea, 1892, p. 122) thus explained the empty river mouth at Cairns:—"The Mulgrave River has evidently at one time entered the sea in Trinity Bay but has been deflected probably by the flows of basalt which fill up its valley down to the point where it turns sharply round to the south to flow into the sea at Port Constantine."



Closer examination of the locality shows that it was not a basalt flow that turned the Mulgrave. Actually it was dammed back from the sea by the sudden outburst in its path of a volcano, locally known as Green Hill. As this recent crater has not been mapped or noted in literature, the following account is submitted:—

Green Hill is visible from the wharf at Cairns, appearing in the south at a distance of seven miles as a truncated cone starting up from flat country. The brown colour of it is in contrast to both foreground and background. A good view of it may be had from the North Coast Railway, between Edmonton and Gordon Vale. From the latter town it is distant about three miles in an E.N.E. direction. Viewed here at right angles to its major axis, the hill resembles in contour the famous Diamond Head at Honolulu.

Green Hill is of the same age and general structure as the volcanic foci around Yungaburra, such as Lake Eacham, and may be regarded as a distant outlier of their family. It is not precisely in the centre of the trench valley but at a third of the breadth from the eastern side. Both the hill and a circumferential area is of tuff, with here and there a basalt boulder or pebble. Frequently these are scoriaceous and they are probably bombs. A creek running out of the crater had cut about ten feet down, showing tuff throughout the section. The volcanic deposit covers an oval area of perhaps two miles by one and extending furthest southwards. Round the base of the crater the ground is only a few feet above sea level, while the summit is about 400 feet. The north wall is very steep, but the crater is breached on the south and descends more gently.

Farmers in the neighbourhood said that the hill was originally covered with scrub, hence the name of Green Hill. A few live trees persist in the crater, otherwise the former forest is only represented by dead trees and stumps. Now it is all covered with coarse grass. The agricultural value of the volanic soil was understood by the pioneers and the tuff was all planted with sugar-cane in the early days. Afterwards the plantation became so heavily infested with cane grub that it was abandoned and is now used for grazing.

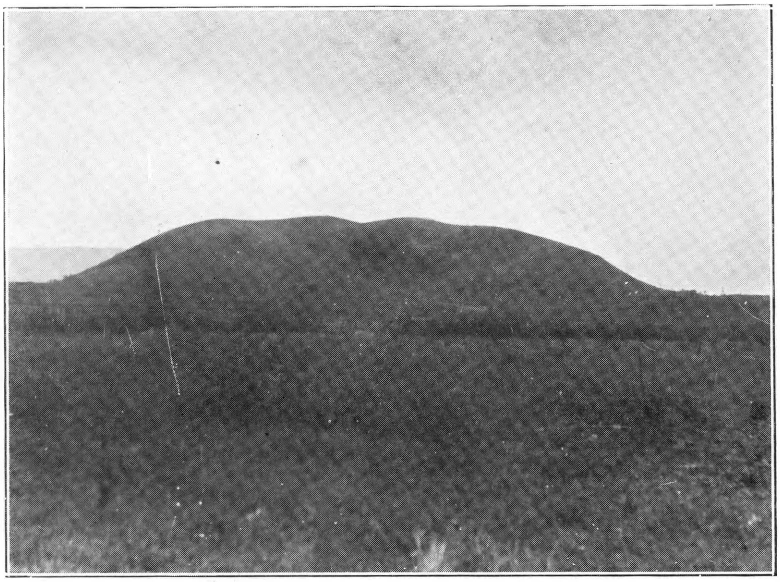
Postscript.

Since the preceding article went to press, I have been reminded of an important memoir by Dr. J. V. Danes entitled "La region des rivieres Barron et Russell" (Annales de Geographie XXI., 1912, pp. 346-363).

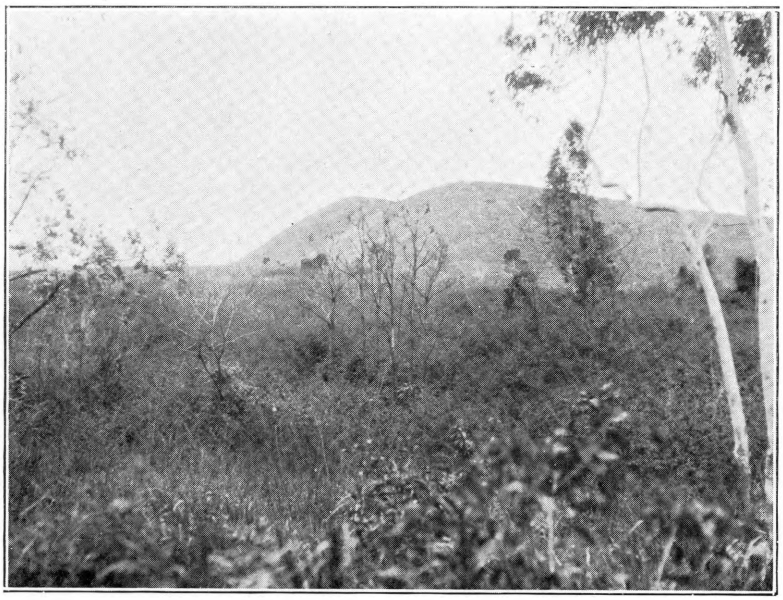
The subject of my essay is here treated with greater skill, knowledge, and thoroughness than I could command. Dr. Danes discovered Green Hill as a volcano, mapped it, and described how it had turned the Mulgrave River from its former estuary in Trinity Inlet.

At this point I considered the withdrawal of my article, but refrain from doing so on the ground that it may convey information to Australian readers to whom this memoir of my friend is not accessible.

Dr. Danes regards the trench valley, of which I wrote, as having a tectonic origin. This observation emboldens me to express a thought that I had suppressed, which is, that this valley is a flexure of the crust, that the volcano stands over a rupture of a syncline floor, and that raised river terraces near Geraldton may have been elevated by an upward roll of the synclinal limb.



GREEN HILL VOLCANO. CONE FROM ¾-MILE SOUTH.



GREEN HILL VOLCANO. RIDGE OF TUFF IN FOREGROUND, DOUBLE SUMMIT OF CRATER IN DISTANCE.

Face page 72.]

THE PHYSIOGRAPHY OF THE PORT CURTIS DISTRICT.

F. JARDINE, B.Sc., Science Research Scholar, Deas Thomson (Mineralogy) Scholar, John Coutts Scholar, University of Sydney (co-operating with the Great Barrier Reef Committee).

(Eight Text Figures.)

No. 12.

SCOPE OF INVESTIGATION.

In a previous paper,[1] some of the features of the Lower Fitzroy basin from The Gap to Keppel Bay were described. In this paper, which is complemental, a description is offered of the coastal area south of Keppel Bay, embracing the betrunked portion of the Fitzroy, thus concluding the investigation of the Lower Fitzroy River. A general description of a large area and more detailed descriptions of various coastal topographic units are given. A correlation is suggested between certain features of the contiguous part of the Great Barrier Reef and the old Fitzroy basin.

LOCATION OF AREA.

The area described is the coastal strip extending from Keppel Bay on the north to Baffle Creek about 100 miles to the south. On the west the area is bounded by the Mount Morgan plateau scarp.

PREVIOUS LITERATURE AND ACKNOWLEDGMENT.

An early account of Port Curtis is that given by Macgillivray,[2] the scientist aboard the "Rattlesnake," commanded by Captain Owen Stanley. The "Rattlesnake," accompanied by the tender "Bramble," was detailed to make a survey of Port Curtis and part of the Inshore Passage leading to Torres Strait. The boats arrived in Port Curtis on 8th November, 1847, a few months after the abandonment by Colonel Barney and party. Macgillivray recorded the discovery of the South Channel entrance to the port. Flinders had charted only the North Channel entrance, a much narrower and more dangerous passage, now closed to shipping. The environs of Port Curtis did not favourably impress Macgillivray, who wrote, "The country for several miles around is barren in the extreme, consisting for the most part of undulating, stony, forest land."

A considerable amount has been written regarding the geology of this area. As early as 1855 Mr. S. Stutchbury published a

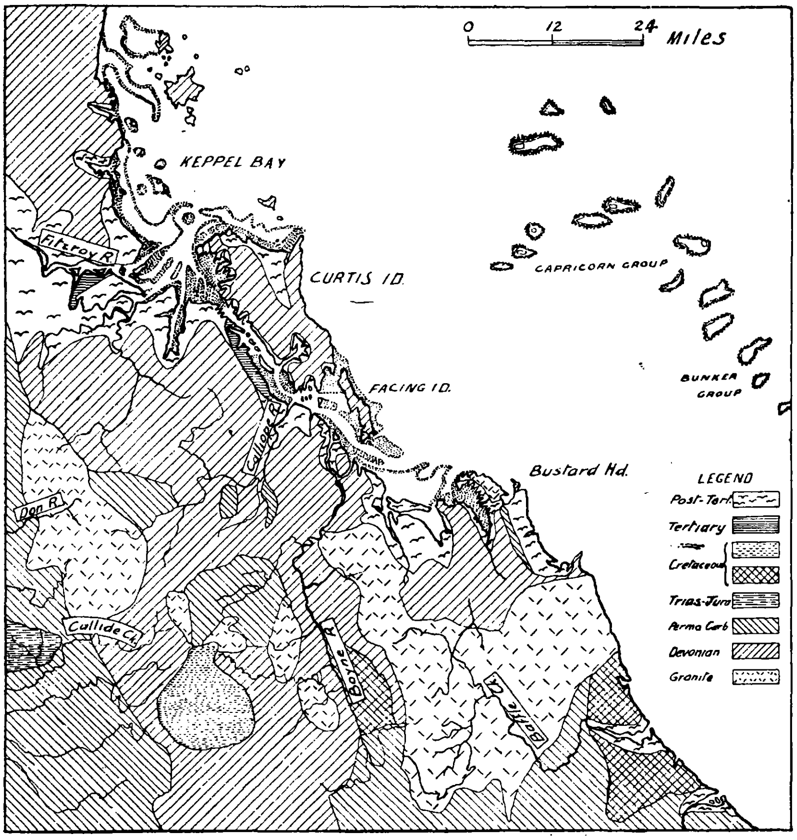


Fig. 1.—Geological Sketch Map of the Port Curtis District.

[*From the Queensland Mineral Index.*]

geological report on the Port Curtis district. Subsequently, many papers, dealing chiefly with the economic geology of the area, have been published, and these contain valuable lithological information. Certain of these publications are mentioned in the appended list of references.

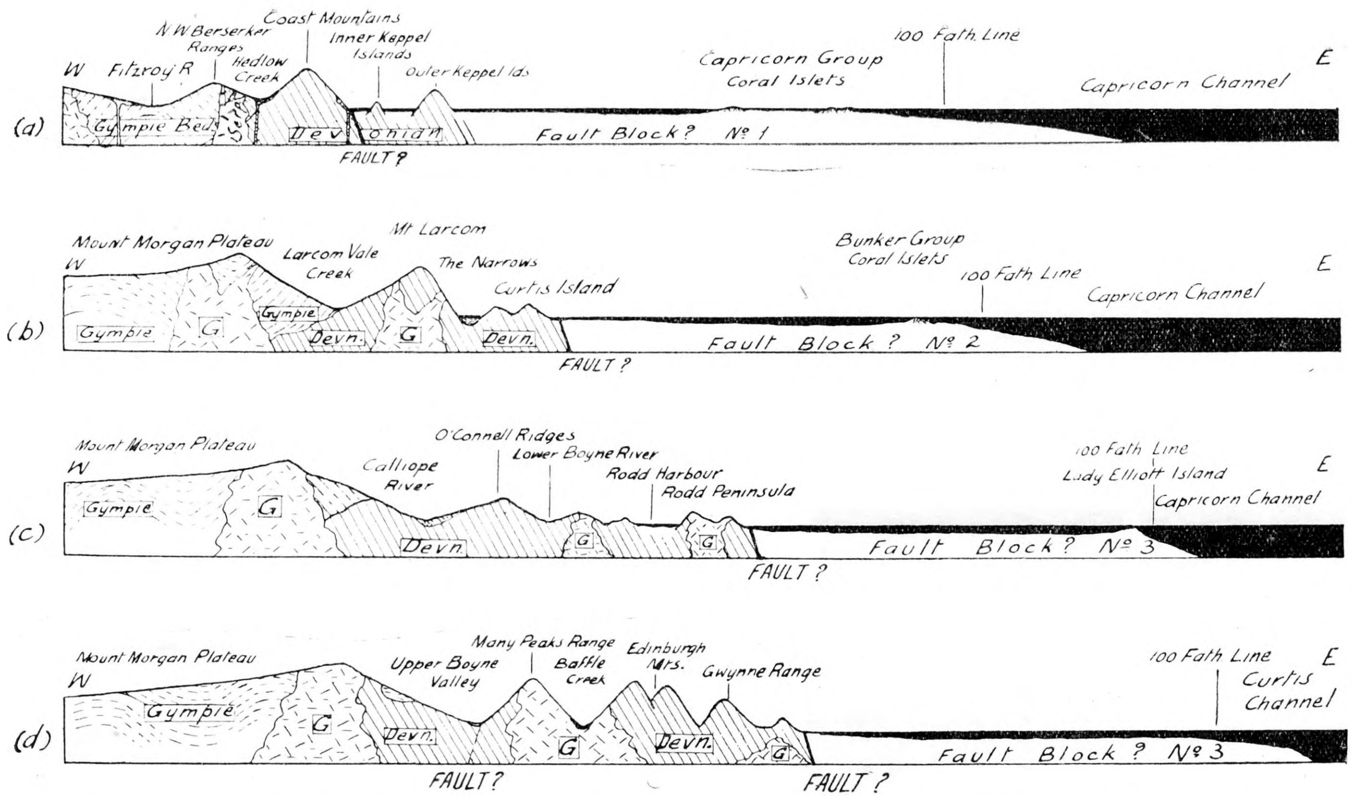


Fig. 2.—East-west profiles illustrating the topographic features of the Port Curtis District, from north (a), to south (d). The geological formations are merely indicated. The vertical scale is approximately $\frac{1}{2}$ inch = 2,000 feet.

The writer wishes to acknowledge the assistance accorded him by the Great Barrier Reef Committee, which generously provided transport facilities.

GEOLOGICAL STRUCTURE. (Figs. 1 and 2.)

The structural geology of the area is not known. Both major and minor faulting have been demonstrated in limited areas which have been mapped. Both folding and faulting have complicated the areal distribution of the formations, and, until this has been more accurately determined, interpretations of the more delicate topographic features must, of necessity, be largely conjectural. Profiles have been drawn to illustrate the physiography. The evidence of faulting shown is discussed in another section of this paper.

DISCOVERY: EARLY SETTLEMENT.[17]

In Cook's logs, no reference occurs to the area between Bustard Head and Cape Capricorn. Bustard Head and Round Hill Head were named North and South Heads respectively, by Cook, and the intervening bay he called Bustard Bay.

Port Curtis was discovered and named by Flinders,[14] in August 1802. Flinders mentioned that "this part of the coast had been passed in the night by Captain Cook, so both openings escaped his notice and the discovery of the port fell to our lot." The "Investigator" was accompanied by a smaller vessel, the "Lady Nelson," under the command of Lieutenant John Murray.[15] On 5th August the opening between Facing and Curtis Islands was observed, but the vessels were unable to enter on account of foul ground. The "Lady Nelson" entered the port by the North Channel, and Flinders explored the harbour in his whaleboat. After a stay of some days, Flinders entered Keppel Bay on 10th August and left on the 18th, after making a fairly accurate survey of Port Curtis and Keppel Bay. In Murray's chart, The Narrows, as well as the openings of Auckland Creek, Calliope River, Connor Creek, and the Fitzroy mouths, are indicated though not named. Flinders was not favourably impressed by the country surrounding Port No. 1, which he named "in honour of Admiral Sir Roger Curtis, who had commanded at the Cape of Good Hope, and been so attentive to our wants." He also named Sea Hill, Mount Larcom, Hummocky, Curtis, and Facing Islands, and Gatcombe Head.

On 30th May, 1819, the "Mermaid," commanded by Captain P. P. King,[16] entered the bay which is bounded on the east by

Rodd Peninsula. This had been overlooked by Flinders, and was named by King, Rodd Bay. King wrote, . . . "The hills which surround the bay are rocky; and, although they are not deficient in wood and grass, the soil is very shallow and the trees, principally of Eucalyptus, are of stunted growth."

Subsequently it became necessary to divert the stream of convicts which was pouring into Tasmania, for the supply of labour exceeded the demand. The Gladstone Administration decided that the diversion should be made into the uninhabited regions of North Australia. The Surveyor-General of New South Wales, John Oxley, was despatched by the Governor, Sir Charles Fitzroy, to search for a suitable site for a new convict settlement. Oxley reached Port Curtis on 5th November, 1823. He reported strongly against the site: . . . "I do not think that any convict settlement could be formed there, that would return, either from the natural productions of the country, or as arising from agricultural labour, any portion of the great expense which would necessarily attend its first formation." However, John Uniacke, a member of the expedition, was more optimistic. He wrote, "The soil here was of the richest description, and calculated to grow cotton, sugar, indigo, and all other Indian productions." Oxley named the stream flowing into Port Curtis, the Boyne River.

By 1846, preparations were advanced for the establishment of a colony, to be called North Australia. This was to be an independent colony, and Colonel George Barney was appointed superintendent. Barney left Sydney in the "Cornuba" in 1846, to select a site for the settlement. Bustard Bay and Rodd Bay were examined, but Port Curtis was finally selected.

On 8th January, 1847, the "Lord Auckland" left Sydney carrying the administrative personnel of the new colony. On 25th January, when about four miles east of Gatcombe Head, Facing Island, the "Lord Auckland" grounded and the passengers were landed on Facing Island, where a camp was established. From the outset, ill-luck seemed to dog the colonists. The "Thomas Lowry," which left Sydney on 26th February with the main stores, was delayed for over a month. The colonists, inactive and without adequate food supplies, were extremely discontented. The arrival of the schooner "Secret" and a cutter, "Harriet," temporarily alleviated the distress. Both were laden with timber which Barney purchased. The timber was landed on South Shore Head, the site selected for the permanent settlement. The camp on Facing Island was maintained, for Barney "did not feel called upon to come to any hasty decision as to the site of the settlement."

In July, 1846, Earl Grey succeeded Gladstone as Secretary of State for the Colonies, and the British Government decided to abandon the project of the establishment of the colony of North Australia. Instructions to this effect reached Barney in April 1847, and the evacuation was effected with remarkable expedition.

As the pastoral industry expanded northward, the establishment of a permanent settlement on the shores of the fine harbour of Port Curtis was inevitable. In 1854, Sir Maurice O'Connell was appointed Government Resident, Police Magistrate, and Commissioner of Crown Lands, at Gladstone. In April 1854, the Governor, Sir Charles Fitzroy, visited the settlement in H.M.S. "Calliope." Stutchbury had discovered traces of gold in one of the streams flowing into Port Curtis. Sir Charles was keenly interested in this discovery, and named the river the Calliope. Following the discovery of gold at Canoona on the Fitzroy, a rush, unique in the history of gold discovery in Australia, occurred in 1858. During this rush, Gladstone was the terminal port where thousands of miners—estimated at 16,000—disembarked.

The settlement at Gladstone did not develop as rapidly as was anticipated. The Fitzroy River to the north offered better access to the hinterland, and the settlement of Rockhampton advanced more rapidly and overshadowed that at Gladstone, which was incorporated in 1863.

PHYSIOGRAPHY.

General.

In this area the coast-line trends from S.W. towards N.W. roughly. Approaching Cawarral Creek in the north, the alignment is broken and the coast trend is N.N.E., forming a shallow indentation into which the Fitzroy enters from the west. The northern part of Curtis Island is distant about ten miles E.N.E. from the Fitzroy mouth. This island trends parallel to the coast for about twenty-five miles and is separated from the mainland by a narrow tidal passage, known as The Narrows. The northern part of the island forms the southern boundary of Keppel Bay. South of Curtis Island, and in alignment, is Facing Island, which is much smaller. This island bounds Port Curtis on the east. About seventeen miles to the south the coastal trend is broken by Rodd Peninsula, on the northern side of which is Rodd Bay. Bustard Bay occurs on the eastern aspect of the peninsula. From the southern boundary of the bay—Round Hill Head—the shore-line, here low, trends S.E. into Hervey Bay.

The eastern scarp of the Mount Morgan plateau, or the divide between the Dawson waters and the coastal waters, trends from N.W. towards S.E. roughly. This feature has received various names. From north to south it is called successively Dee, Ulam, Calliope, Dawes, and Auburn Ranges. The plateau is drained by the Dee River (rising in the Dee Range), the Don River (rising in the Calliope Range), Callide-Kroombit Creeks (rising in the Calliope and Dawes Ranges respectively). These streams unite a few miles south of Dundee, and flow into the Dawson River through the Gogango-Rannes and Leichhardt residuals. From their headwaters to these residuals, the streams fall about 400 feet. Each occupies a well-defined headwater basin, the eastern rims of which are the various ranges by which the plateau scarp is known. The N.W. and S.E. rims or lateral divides, in some cases, have been named—the Callide Range between Callide Creek and one of its tributaries Bell Creek, the Gelobera Range between the Dee and the Don Rivers.

The east-flowing coastal streams have effected considerable deplanation. The dissected coastal belt extending from the Dee Range on the north, to the Calliope Range on the south, is a strip forty to fifty miles broad. It is drained by Station, Inkerman, and Raglan Creeks which enter the Fitzroy delta, Calliope and Boyne Rivers which enter Port Curtis. The stream basins are well defined. The divide between the Fitzroy waters and Calliope waters is known as the Mount Alma and Mount Larcom Ranges; that between the Boyne and Calliope Rivers is the Boyne Range and its prolongation, O'Connell Ridges. The Milton Range divides the waters of Diglum and Degalgil-Marble Creeks; Table Range is the divide between Glassford and Ridler Creeks, all Boyne waters.

Baffle Creek enters Hervey Bay about twenty miles south of Round Hill Head. It is an extremely asymmetric system of streams, roughly in the form of a W, oriented N.W. and S.E., having an outlet to the S.E. The divide between the west and central streams (Granite and Baffle Creeks) is the Bobby Range. Between the eastern stream (Oyster Creek) and Baffle Creek, the divide is known as the Edinburgh Mountains, Westwood and Gwynne Ranges. The Baffle Creek waters are cut off from the Boyne waters by the Many Peaks Ranges.

The Dawes Range, where it forms part of the plateau scarp, trends S.W., and the scarp in the Auburn Range is distant 100 miles or more from the coast. This retreat is due to the great notch cut by the Burnett River. To the north, the Dawson receives the Dee and Don Rivers, but these are the only large streams which do enter the river from the east.

About twelve miles below the mouth of Baffle Creek the Kolan River enters Hervey Bay. The divide between Baffle Creek and the Kolan River is known as the Watalgan and Dawes Ranges; that between the Burnett and Kolan is the Burnett Range.

DETAILED PHYSIOGRAPHY.

CURTIS ISLAND. (Fig. 3.)

Curtis Island is about twenty-five miles long and twelve miles broad at its widest part. Structurally, the island is composed of an eastern line of hills (which for convenience is called an axis), running from Cape Capricorn (Capricorn Hill 300 feet), to the southern end of the island to View Hill (414 feet). These hills form the shore-line, which is a broken succession of cliffs, rocky headlands, and sandy coves. The western axis of hills is broader and commences south of the old Pilot Station on the north. It broadens in the Ramsay Range (456 feet) and Coast Hills (415 feet) and trends along the western shore of the island, finally joining the eastern axis in the south. The western shore is broken by considerable indentations or estuaries, into which short streams drain. The foreshores are extensive mudbanks, and there is an enormous development of fringing mangrove swamps. The northern shore of the island, between the eastern and western axes, is uniformly low and is fringed by sandbanks. The low ground extends down the centre of the island, which is of the nature of a broad flat valley. A considerable area of this low ground is subject to inundation during the spring tides; further south, the flats are low and swampy and provide excellent pasturage. They are known as the Marine Plains. Several aneroid readings indicated that the Marine Plains are elevated 15 to 30 feet above high-water level. In this valley, several monadnocks occur about 300 feet high, inliers rising through the alluvium.

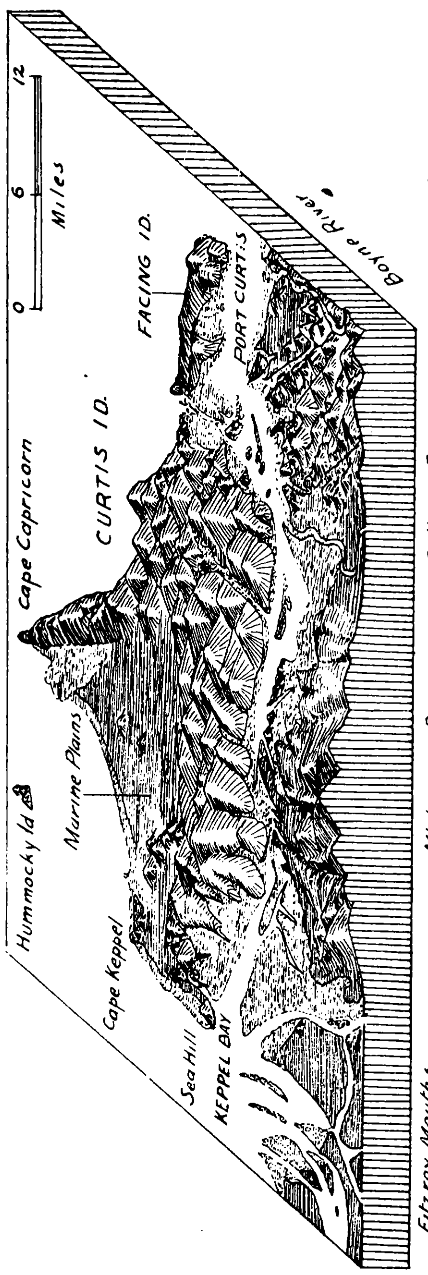


Fig. 3.—Curtis Island and the Narrows Area. Generalised Topography.

The writer found no evidence of marine life on the plains in this locality. A marginal strand-line is apparent but beach deposits were not observed.

On the western side of the Cape Capricorn peninsula, a prominent landmark, the "yellow patch," occurs. This is the plane of repose of sand, wind-driven from the S.E., which is derived from the disintegration of the arenaceous rocks of the peninsula.

To the west and east of the old Pilot Station on the northern end of the island, Sea Hill (310 feet) and Cape Keppel Hills (290 feet) occur. These are fluvio-marine monadnocks also, and are isolated from the western axis of hills by smaller but similar marine plains to those described. Sea Hill is an inlier in recent beds which have been deposited under marine conditions. Around the base of the hill on the south, the recent unstratified deposits are composed of comminuted shell fragments, with many well-preserved shells. These, apparently, are similar to the modern beach-shells of the locality. The beds are here ten to fifteen feet above high-water mark. The "marine plain" which ties-on Sea Hill is small; that which ties-on Cape Keppel is larger and is connected with the main marine plain by a narrow strip to the north of Coast Hills. Mr. Dunstan recorded that the rocks in the north of the island consist of slates, quartzites, and fine-grained sandstones, which dip to the east at 30°. The writer could not identify the strike with any certainty at Sea Hill or Cape Keppel. At the latter place, the rocks are manganese-bearing. Stutchbury[3] recorded that the rocks on the south end of the island consisted of schists and jasperised slates, striking N.E. and dipping S.W.

Graham's Creek, a broad and fairly deep channel, penetrates from The Narrows in the south, through the western residuals to the central lower area, where it expands in a broad swampy basin. Its course is fringed by mudbanks and mangrove swamps.

At a period not remote Curtis Island was much reduced in size. A large bay opened into the island from the N.W., occupying the Marine Plains, with Cape Keppel and Sea Hill Islands in Keppel Bay. Silting, and a slight lowering of sea-level, have resulted in the reclamation of the flats and the tying-on of these two islands. Mr. E. C. Andrews[18] has briefly described some of the features of Curtis Island, and appended notes by Mr. C. Hedley.

FACING ISLAND AND THE ISLANDS OF PORT CURTIS.

The eastern axis of Curtis Island is prolonged southward in Facing Island. The passage between these islands, the North Entrance to Port Curtis, is narrow, shoaled and fouled by submerged rocks. South-east of Facing Island, a break of ten miles occurs—the entrance to Port Curtis—and the trend of the hills is continued in the low hills fringing Seven-mile Creek and the Westwood Range.

The western axis of Curtis Island is continued southward in a number of islands in Port Curtis, whence it may be traced on to the mainland in the hills of Auckland Point.

Facing Island is about eight miles long and one to three miles broad. The highest point on the island occurs in the south (245 feet), and from here the island slopes to the north. The eastern shore-line is somewhat similar to that of Curtis Island, while the western shore-line is less linear and is fringed by sand-shoals and mud-flats. On the north-west, the rocks are slates and schists; in the east, micaceous slates occur, striking N. 15° W. and dipping westwards. Towards Gatcombe Head the schists are much contorted and strike N. 15° E., and are traversed by dykes of granite.[3]

The islands of Port Curtis include Campigne, Quoin, Turtle, Diamantina, Witt, Tide, and Picnic Islands, and many smaller rocks. These consist of sandstones, quartzites, and schists. Frequently, the latter are intensely crumpled and intruded by quartz stringers.

THE ISLANDS OF KEPPEL BAY. (Fig. 4.)

The writer previously commented on the linear arrangement of the islands of Keppel Bay. This alignment coincides with the axes of Curtis Island. The eastern axis is prolonged into Keppel Bay in Fairway Rock, Ship Rock, Hummocky Island, Humpy Island, Halfway Island, Great Keppel Island, Middle Island, Myall Island, Sloping Island, North Keppel Island, Corroboree Island, and Conical Rocks. The prolongation of the western axis of Curtis Island is found in the Keppel Rocks, Arch Rocks, Peak Island, Split Rock, Divided Island, Wedge Island, Pelican Island, and thence to the coastal ranges south of Yeppoon.

A further zone of islands occurs four to five miles east of the North and South Keppel Islands, in Egg Rock, Barren Island, The Child, Man and Wife, and Outer Rock. The islands of these

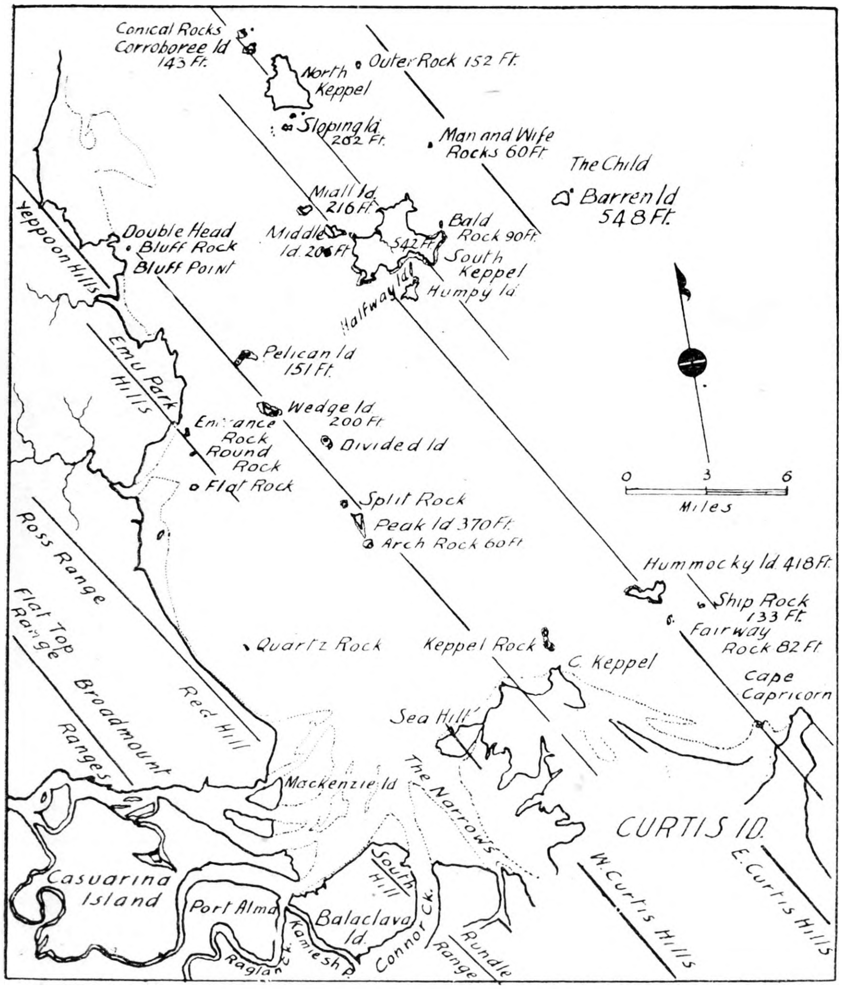


Fig. 4.—The Islands of Keppel Bay.
The trends of the residuals are indicated by lines.

three zones are composed of altered sedimentary rocks, considered to be Devonian in age. Some account of the geology of the islands has been given by Jack and Dunstan.[19] Keppel Rocks are quartzite and contorted shales, which strike N. 10° W. and dip vertically, or steeply to the west. Veins of turquoise traverse the beds. Arch Rock, Peak Island, Split Rock, and Divided Island are composed of quartzites, shales, or schists. On Peak Island the quartzites dip steeply to E. On the N.W. of South Keppel Island, quartzites and shales strike W. 22° N. and dip towards S.W. at 25°. Middle and Myall Islands are of quartzite.

Between Emu Park and Yeppoon, close inshore, Bluff Rock and Creek Rock, as well as Doublehead and Bluff Point, are plugs of trachyte. These occur where the inner zone of islands trends onshore.

North Keppel Island.

North Keppel Island is shaped somewhat like a right-angled triangle, with the right angle directed towards the S.E. Its length, north and south, is about two miles, and breadth towards the south is slightly less. The island is composed of a series of gently dipping sandstones, quartzites, mudstones, and phyllitic rocks. On the south side of the island, the rocks (sandstones) strike E. and W. and dip to the N. at angles of 15°-20°. On the N.E. side of the island, the rocks strike W. 30° N. and dip to the N.E. at 15°. The north-east side of the island is precipitous, but the southern and western shores are more indented, with rocky headlands and sandy coves. Along the southern shore a strand-line can be traced. Bluffs, which have their profiles softened, are covered by vegetation. These have been formed by the truncation of the hill-slopes, and overlook wave-built terrraces up to 150 paces broad, which are composed of a dark sandy loam, with disseminated shells and coral fragments. Such a terrace occurs on the south-west of the island, marked by a clump of coconut trees. Westward, the terrace is covered by a grove of casuarinas. Here, wave-erosion is rapidly removing the terrace (about 200 yards broad); the she-oaks are being undermined, and fallen trees are strewn along the beach. The terraces are twenty feet above high-water level. Further east, a terrace has been covered by wind-driven sand, which forms dunes thirty to forty feet high. On the crests of these ridges, aboriginal flakes and hammer-stones may be readily picked out. In the N.E. shore-line, benches have been developed. These are described in another paper. Fringing the southern shore, inextensive growths of coral occur.

Great (or South) Keppel Island.

This island is somewhat rectangular in outline. A marked feature is the characteristic N.W. trend of the hills. The western axis of the island is prolonged to the south-east in Humpy and

Halfway Islands, and to the north-west in Middle and Myall Islands. The eastern axis is prolonged to the south-east in Hannah Rock, and to the north-east in North Keppel and its adjacent islands. About four miles eastward of North and South Keppel Islands, the zone containing Egg Rock, Barren Island, Man and Wife Rocks, and Outer Rocks occurs.

The writer did not land on this island. Descriptive notes will be found in Macgillivray's book.[2]

The Narrows.

The tidal channel connecting Keppel Bay with Port Curtis is known by the general name of The Narrows, though this name was originally applied only to the passage through the bar in the vicinity of Monduran Creek, now known as the Ramsay or Monte Christo Crossing. The mainland shore slopes up to the Mount Larcom and Rundle residuals, which in Mount Larcom are 2,060 feet high. The Rundle Range slopes rapidly away towards the Fitzroy mouth. The streams draining into The Narrows are small, Monduran Creek being the only one of any magnitude. This stream rises in a notch cut in the Mount Larcom Ranges, and flows in a N.N.E. direction. Fringing The Narrows, there are extensive mud-flats and dense mangrove thickets. The waterway varies in breadth up to four miles, but the channel is restricted, being one-quarter of a mile wide and less. Numerous sandbanks in the channel considerably reduce the available waterway. Several inliers occur rising through the western foreshores of the channel, attaining an elevation of 168 feet. Streams of the nature of distributaries meander through the mud and mangrove flats, e.g. Black Swan and Deception Creeks. The bar at Ramsay Crossing is composed largely of shingle. This bar was originally four feet six inches above low-water level, but by dredging, and excavating during low water, the channel has been deepened by about three feet. The tide enters The Narrows both from Keppel Bay and Port Curtis, and the bar of shingle at The Crossing appears to be associated with the meeting of the tides in the vicinity. The springs rise here ten to fifteen feet. After meeting, the Keppel Bay tide forces the Port Curtis tide southward.

Mr. Ball describes The Narrows as being "a drowned valley of typical form."[10]

PORT CURTIS.

The harbour of Port Curtis is described in the Admiralty publications as being one of the safest and most capacious in Queensland. The East Banks extend from Facing Island in a S.W. direction. Between the island and this bank is the North Channel. Sandbanks extend eastward from Tiber Point, Colosseum Inlet, and through these the Seal Rocks project. The Jenny Lind banks occur still further east. These form the southern limits of the main entrance to the port, the South Channel. The North Entrance is available for small boats only. The North Channel has been closed to shipping on account of shoaling. The northern part of the harbour is fouled by numerous shoals which fringe the islands. The entrance to the port is clear, with deep water to Auckland Point.

RODD BAY AND RODD PENINSULA. (Fig. 5.)

The features of this locality closely resemble those of the Keppel Bay-Curtis Island area. Here, lines of residuals occur trending N.W. and S.E. with intervening valleys. In Rodd Peninsula, two axes of residuals occur. The eastern axis is fragmentary and is found in Jansen, Outer, Middle, Inner Rocks, and Bustard Head. The western axis is found in the Bray Hills (rising to 560 feet in Table Hill) and continued south-eastwards in the Munro Ranges (1,060 feet). Rodd Peninsula is isolated from the mainland by Rodd Harbour and low ground across which, at high tide, a channel connects Rodd Harbour with Pancake Creek. The peninsula may be likened to Curtis Island, and Rodd Harbour is the analogue of The Narrows. A line of residuals trends from N.W. to S.E. fringing Rodd Harbour on the west, and is continued southwards in the Edinburgh Mountains (1,525 feet), Westwood Range (1,650 feet in Arthur's Seat), Gwynne Range (1,262 feet), and Maria Ranges (1,100 feet). These correspond to the Rundle-Mount Larcom residuals of The Narrows area. To the west, the delta lands of Colosseum Creek and Seven-mile Creek correspond to the delta lands of the present Fitzroy mouth. Into these delta lands short streams, Twelve-mile Creek (into Colosseum Inlet) and Scrubby Creek (into Seven-mile Creek), drain from the low divide to the S.E., which separates these waters from the Baffle Creek waters.

Bustard Head is isolated by the inlets of Pancake Creek on the north and Jenny Lind Inlet on the south. At the head of

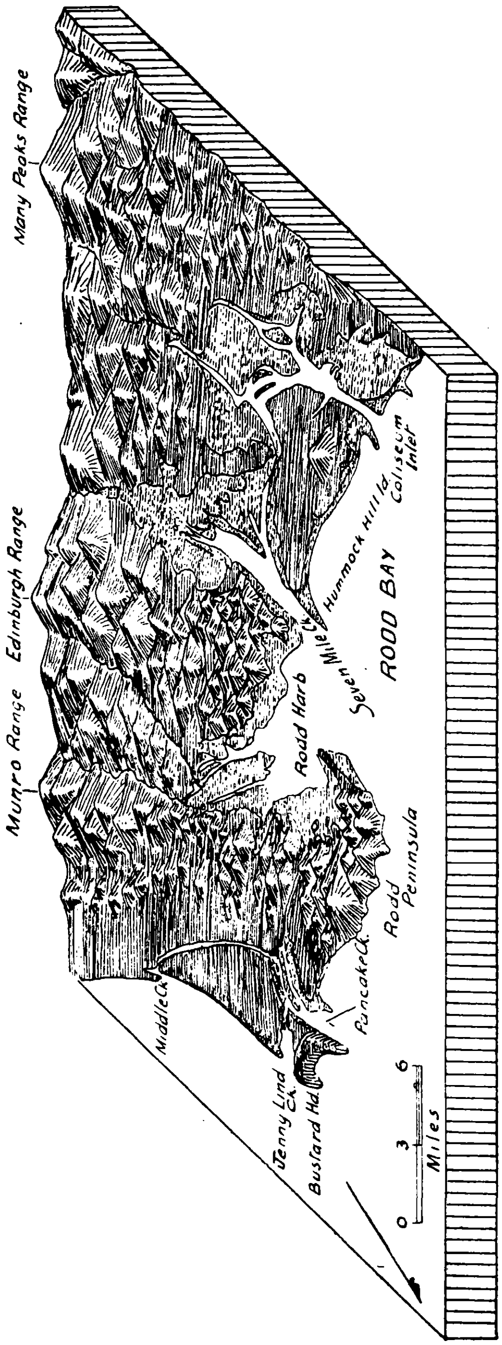


Fig. 5.—The Rodd Bay Area. Generalised Topography.

Pancake Creek, Middle Creek sweeps round and enters Bustard Bay, cutting off an area, Middle Island, from the mainland. The shores of Bustard Bay are low and swampy. The shores of Rodd Harbour consist of low ridges fringed by extensive mangrove swamps. The harbour waters are encumbered by extensive sandbanks and mangrove islands. The low-lying flats about Colosseum and Seven-mile Inlets are intersected by a maze of waterways, one of which, Boyne Creek, connects the inlets at high water, isolating Hummock Hill Island through which an inlier, Hummock Hill, rises to 450 feet.

THE HIGHLANDS OF THE AREA.

The importance of rock strike in determining the course of the Lower Fitzroy was suggested by the writer. In the Port Curtis district this control is even more pronounced, and has been pointed out by Mr. Ball.

In this area, the control is best indicated by the trend of the residuals in the basins, carved out of the plateau by the streams. These form a more valuable index than the present stream courses, for the latter are the results of evolutionary changes during the erosion cycle.

The trends of the residuals in the Port Curtis area show a parallelism of alignment, and may be divided into two systems, viz., those which trend roughly N.W. and S.E., which are dominant, and those which trend roughly at right angles, which are generally speaking of less relief. Five lines of residuals may be traced trending N.W. and S.E., viz.:—(1) The Ranges of the Plateau scarp; (2) Rundle (1,031 feet), Mount Larcom (2,060 feet), O'Connell (800 feet), Boyne, Many Peaks Ranges (2,430 feet); (3) the Inner Keppel Island line (600 feet), the hills of Auckland Point (200-300 feet), Colosseum Mountain (1,646 feet), Palmer or Grevillia Mountains (1,480 feet); (4) the eastern Curtis Island ridges, Facing Island, Edinburgh Mountains (1,525 feet), Westwood (1,650 feet), Gwynne (1,300 feet), and Maria (1,100 feet) Ranges; (5) Bray Hills (560 feet) and Munro Range (1,060 feet).

While this linear arrangement is apparent, individual residuals vary in size and dissection, and the continuities of the lines are broken by streams which flow across the strike and which offer evidence of evolutionary changes. The long N.W. and S.E. intermont areas are themselves divided into a series of smaller basins, carved out by the tributaries.

The disposition of the residuals suggests that the modern streams evolved from what, in earlier times, was a system of streams flowing from about S.S.E. to N.N.W., and that these stream courses were determined largely by the rock strike.

The Rivers of the Port Curtis District.

(*a*) *Delta Streams of the Fitzroy River.* (Fig. 6.)

The north entrance to The Narrows is distant from the Fitzroy mouth about seven and a-half miles to the east. Between The

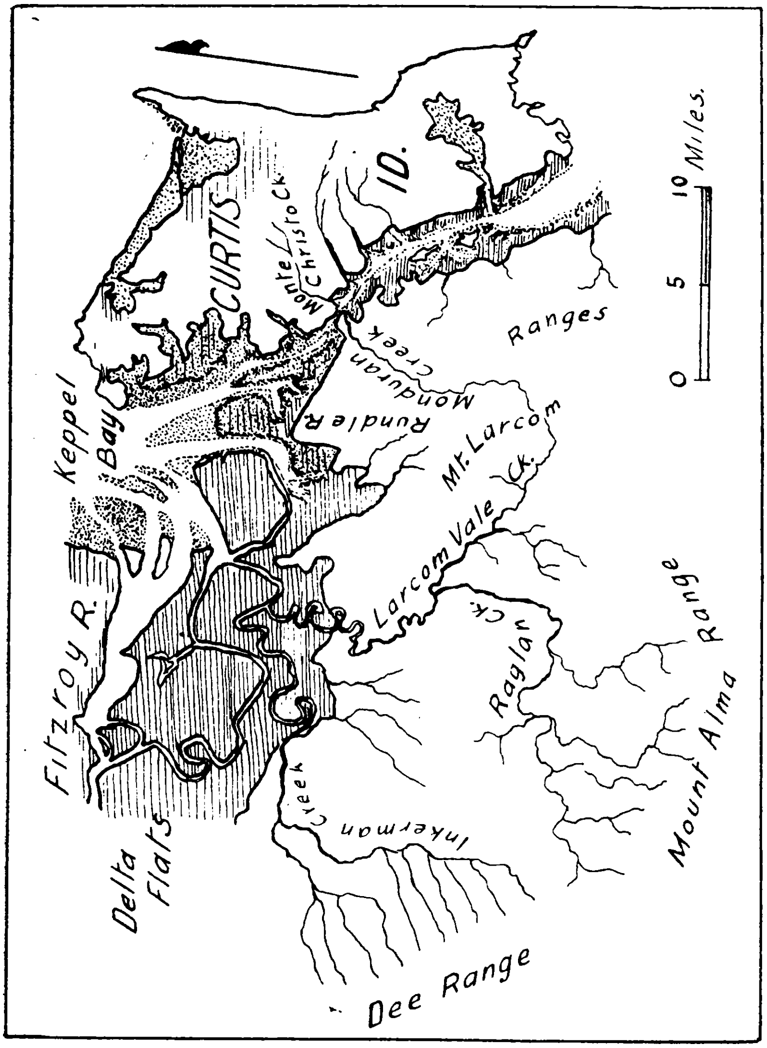


Fig. 6.—The Delta Streams of the Fitzroy River.

Narrows and Port Alma, the southern shore of Keppel Bay consists of mud-flats and mangrove islands, through which distributaries meander. The largest of these, Connor Creek with Kamiesh Passage, cuts off Balaclava Island through which an inlier of Devonian rocks, South Hill, rises 200 feet. From the Mount Larcom Range, Larcom Vale Creek flows N.W. It is joined by Raglan Creek from the Mount Alma Range, and later this stream unites with Inkerman Creek, which rises in the Dee Ranges. In their lower courses, Raglan and Inkerman Creeks meander in the flats in an extraordinary manner. Inkerman Creek flows more or less parallel with Casuarina Creek (a large distributary of the Fitzroy which isolates Casuarina Island) for about eight miles, and although they are only 400 yards or so apart in places they do not unite.

THE CALLIOPE RIVER AND AUCKLAND CREEK. (Fig. 7.)

This stream rises in the Calliope Ranges and occupies a well-defined basin in the headwater area. The general direction of flow is from S.W. to N.E. From the headwater basin, the stream flows N.W. for about three miles, then turns E. for twelve miles, and finally enters Port Curtis after flowing slightly E. of N. for fifteen miles. On the left bank, the river receives Larcom Creek, which, rising in the range of that name, flows across the strike of the rocks from N. of E., and enters the Calliope from the N.W. The upper course of the tributary is roughly parallel but opposite in direction to the Calliope, which it finally joins flowing along the rock strike. The Mount Alma and Mount Larcom Ranges form the divide between the Fitzroy and Calliope waters. These ranges are separated by a broad air-gap, about 150 feet high, rising to over 1,000 feet on either side. On the north side of the notch, Larcom Vale Creek rises and flows to the Fitzroy, while on the south Larcom Creek rises and flows into the Calliope. There are no other streams of importance flowing into the Calliope on its left bank.

On its right bank, the river receives Double Creek from the Boyne Ranges near Pine Mountain. This stream and the lower Calliope are in alignment. About two miles below the mouth of Double Creek, the river falls over the Marble Bar in a series of rapids, through open ridgy country. The stream banks are about fifteen feet high and are composed largely of alluvium. Four or five miles below the Marble Bar, the Calliope cuts through the ridges of Mounts Beecher and Stowe, in a gorge about 300 feet deep. Below this, rock outcrops in the stream are rare. The banks are composed of alluvium, the land surface is much subdued, and the river is fringed with mangroves. Below the Railway Bridge, the land surface is plane, and the river meanders through mangrove swamps, which are intersected by distributaries. The steep banks, incised by the swinging of the stream, are about fifteen feet high and are composed of sand and shingle. Towards the mouth, the banks become lower, and are of mud covered by dense mangrove thickets.

In its lower course, the Calliope receives Clyde Creek, which rises in the Boyne Range and flows N.N.W. A smaller stream, Lexlip Creek, rises also in the Boyne Range and flows W. of N., finally joining the Calliope a mile or more above the Marble Bar. The upper part of Lexlip Creek, a tributary of Diglum Creek, and the Upper Boyne are in alignment.

Auckland Creek (Police Creek in its headwaters) rises in the O'Connell ridges (which divide its waters from those of Clyde Creek), flows to the W. of N., and enters the Calliope delta lands, where it meanders about, finally entering Port Curtis about two miles to the east of the Calliope mouth.

The Boyne River. (Fig. 7.)

The Upper Boyne River occupies a somewhat rectangular basin, whose long axis runs in a N.N.W. direction. On the west the plateau scarp is over 2,000 feet high in places, and on the east the Many Peaks residuals are between 2,000 and 3,000 feet high. The Boyne is disposed asymmetrically in this valley to the east. The dissection is well advanced. From Littlemore, in the head-water region, the river falls 300 feet to the sea, distant about fifty miles.

An interesting feature of the Upper Boyne Valley is the presence of an area of Burrum Beds. South of this area, abnormalities are apparent in the Boyne tributaries, suggestive of captures involving Granite Creek, the Kolan, Burnett, and Boyne Rivers. The writer is unfamiliar with this part. North of the Burrum Beds, the tributaries have eroded, indifferently, sedimentary and plutonic rocks. The asymmetry of the Upper Boyne

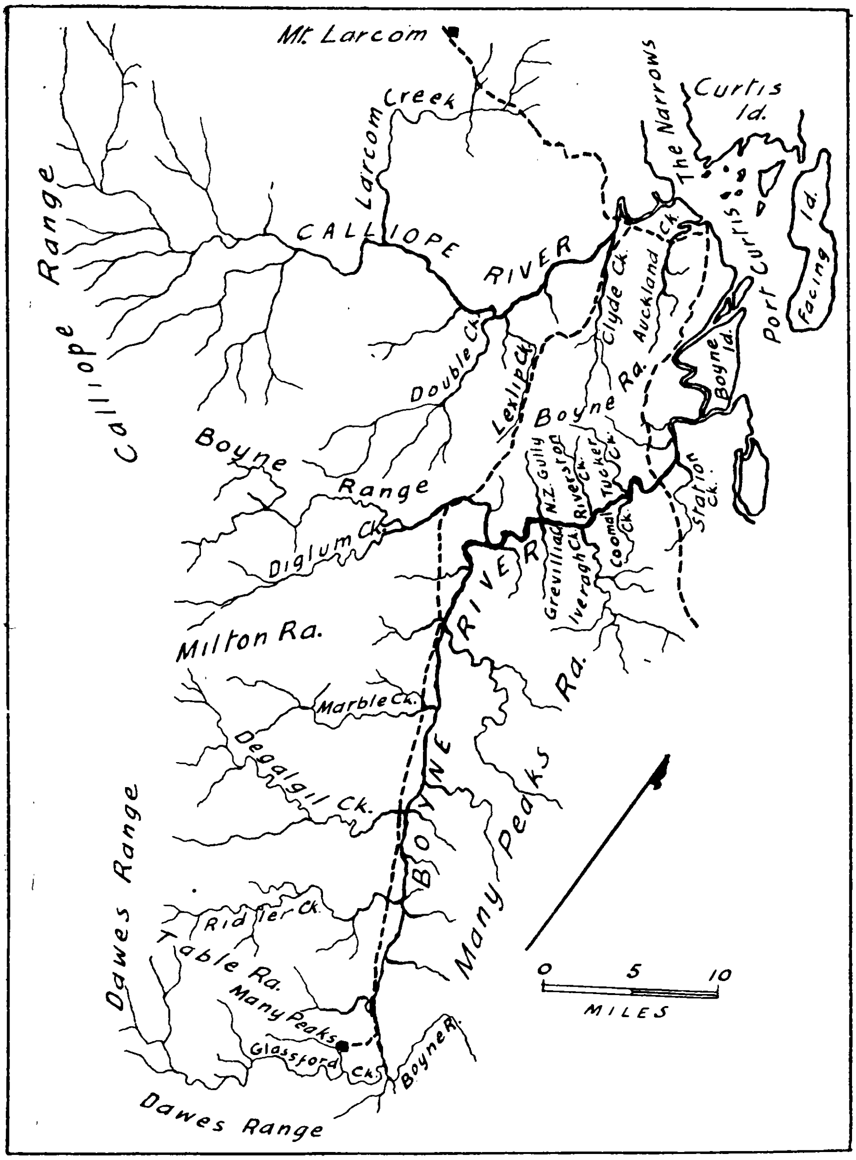


Fig. 7.—The Calliope and Boyne River Systems.

Valley, in the writer's opinion, cannot be ascribed to differential erosion alone. Considered in conjunction with the presence of the Burrum Beds, faulting offers the simplest explanation of this feature. Professor David suggested a fault throwing to the east; the writer suggests that the physiographic features suggest, rather, a throw to the west.

Where the Boyne is joined by Diglum Creek, the river leaves this basin and flows slightly E. of N. between Mount Castletower Ranges (2,048 feet) and the extremity of the Boyne Range. The Boyne Valley Railway passes over the low divide separating Lexlip Creek and a tributary of Diglum Creek. In its lower course, the Boyne tributaries are disposed in a particular manner. They are paired and linear, those on the left bank flowing from the N.W. and those on the right bank from the S.E. Such paired streams are New Zealand Gully and Grevillia Creek, Riverston and Iveragh Creeks, Tucker Gully and Coomal Creeks. Where Station Creek joins the Boyne from the S.E., the river turns to the N.W. for three miles and the two are in alignment. The river again turns to the N.N.E. and enters Port Curtis. About three miles from its mouth the stream bifurcates; one channel flows for six or eight miles to the N.W., then slightly E. of N., and enters Port Curtis by way of South Trees Inlet. The Outer Boyne flows through country of low relief. The topography is similar in the case of the Inner Boyne as far as the head of South Trees Inlet, which is fringed by extensive mangrove flats and saltpans. The land cut off by the Boyne mouths—Boyne Island—is highest in the south, reaching 400 feet in the Lilly Hills. In the N.E., distributaries dissect the island and isolate South Trees Point, which rises slightly above the general level of the flats.

Baffle Creek. (Fig. 8.)

Baffle Creek rises in the low divide south of Rodd Bay in a series of lagoons, and flows S.W. for a considerable distance, when it turns abruptly and flows E.N.E., then N.N.E. for a short distance, finally emptying into Hervey Bay from the west by way of a small delta. On the right bank, Scrubby, Harpur, Granite, Colosseum, and House Creeks meet the main stream, making an obtuse angle on the upstream side. On the left bank, the Westwood-Gwynne Ranges have been breached by a tributary, which receives waters from a curious network of streams. Oyster Creek rises in the valley between the Munro and Edinburgh Ranges, and flows S.W., joining Baffle Creek towards its mouth.

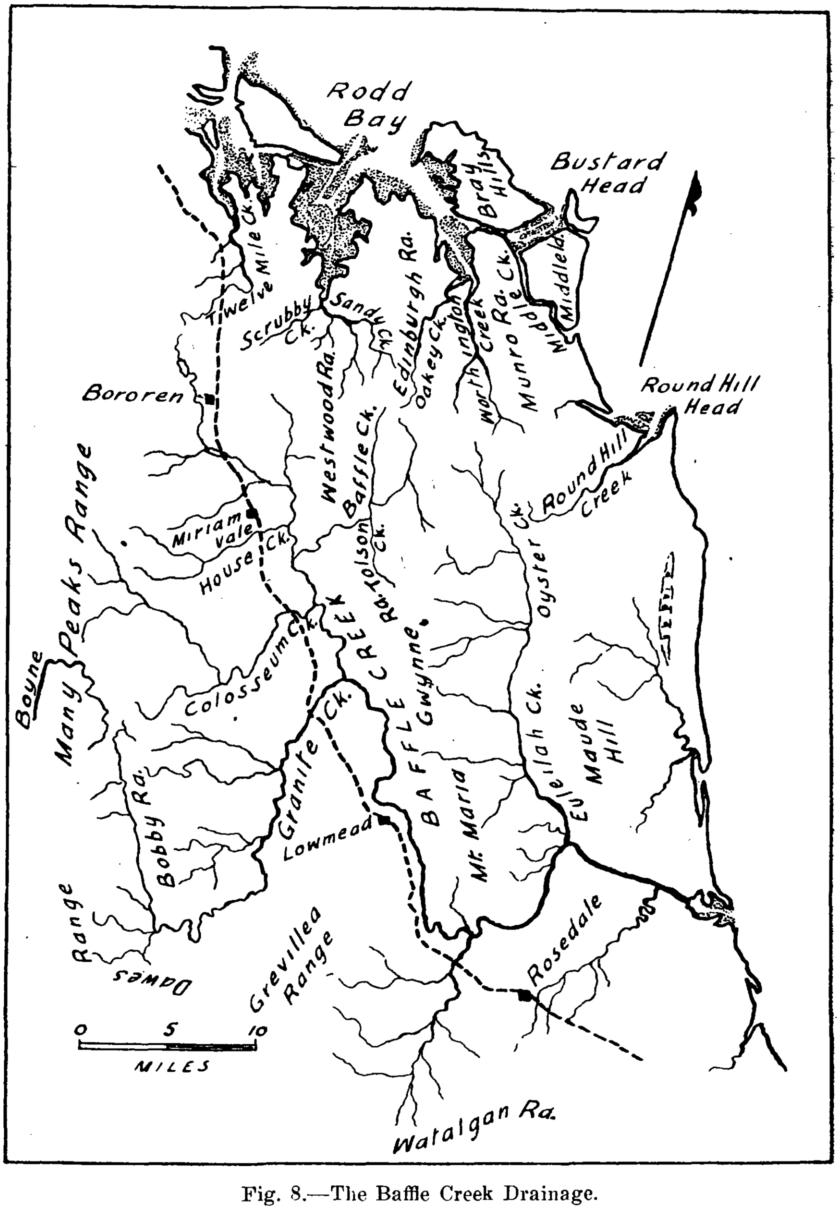


Fig. 8.—The Baffle Creek Drainage.

THE EVOLUTION OF THE DRAINAGE OF THE PORT CURTIS DISTRICT.

The evidence offered by the rivers supports the conclusion drawn from the distribution of the residuals, that the streams of the district have evolved from a N.N.W.-flowing drainage system. As the cycle of erosion advanced, the expansion of tributaries across the strike resulted in the breaching of lateral dividing residuals and the inauguration of the modern stream systems, which have since effected considerable erosion of the plateau.

It is suggested that the Upper Boyne was originally the old Upper Calliope, and flowed on a course approximating to the lower part of Diglum Creek, Upper Lexlip Creek, and Lower Clyde Creek to Port Curtis. A control other than rock strike at one time held the Upper Boyne on a particular course, and allowed a greater expansion of tributaries on the west—possibly the downthrown portion of a strike fault. This fault would not necessarily be of great magnitude; considerable erosion has since been effected, and the stream may or may not, at present, be coincident with the fault plane. In the Lower Boyne, the disposition of the tributaries is such as would have resulted from the capture of N.W.-flowing strike streams (in this case tributaries of the old Calliope), by the headward erosion of lateral streams, represented by the N.E.-flowing segments of the Lower Boyne.

In a somewhat similar manner, the present Calliope has evolved by the capture of the headwaters of Larcom Vale Creek (Fitzroy waters). The pirate tributary of the old Lower Calliope breached the Beecher-Stowe residuals and captured the headwaters of Larcom Vale Creek, relics of which occur in part of the present Middle Calliope and Larcom Creek. The low air-gap between the Mount Larcom Ranges and the Mount Alma Ranges is the old water-gap of Larcom Vale Creek. This capture occurred subsequently, probably, to the beheading of the old Calliope.

In the lower courses of the present streams, the departures from the rock strike are not greater than one would anticipate in streams of such maturity.

Baffle Creek.

A reversal is clearly indicated in the case of this stream, which originally drained into Rodd Bay—a conclusion previously reached by Mr. Ball,[10] who suggested that a slight upheaval of the country immediately south of Rodd Bay may have caused the damming of Baffle Creek and the formation of a lake, in which the Tertiary kerosene shales were deposited; the barrier was cut through to the north, but subsequently reimposed and the drainage of the basin captured by the headward erosion of Baffle Creek.

The occurrence of Tertiary shales in The Narrows suggests that deposition of these beds occurred before the drowning of the shore-line, when freshwater conditions prevailed. The imposition of lacustrine conditions clearly indicates an interruption. It may be assumed that the Baffle Creek and Narrows shales were contemporaneously deposited, and the stream captured by Baffle Creek drained into the old Fitzroy and persisted till after the betrunking of this stream. The method of capture may have been in the manner suggested by Mr. Ball. It is clear that the captures by Baffle Creek did not occur for a considerable time after the deposition of the shales, and that at the time of drowning the north-flowing stream persisted, for the delta deposits of Colosseum and Seven-mile Creek Inlets suggest deposition by a large stream. The writer sees no necessity to postulate the reimposition of the barrier which dammed the north-flowing stream. The gradual encroachment by Baffle Creek, with subsequent erosion by Twelve-mile and Scrubby Creeks flowing into Rodd Bay, and Baffle Creek on the south, would explain the present topography. It is possible that the kerosene shale beds are relics of former extensive basin lake deposits which resulted from the damming of the betrunked Fitzroy.

It is probable that Upper Oyster Creek and Tolston Creek were once the headwaters of Worthington Creek flowing into Rodd Harbour, and that the former was captured by Euleilah Creek, and the latter by the tributary of Baffle Creek which breached the Westwood-Gwynne residuals.

The Betrunked Fitzroy River.

Mr. Dunstan[7] first suggested that the Fitzroy, at one time, drained between Curtis Island and the mainland, at a time prior to the formation of Keppel Bay—a conclusion with which the writer agrees, but differs somewhat from Mr. Dunstan in interpreting the origin of Keppel Bay. The trend of the old Lower Fitzroy can be traced to the S.E. in The Narrows, and Rodd Harbour, and the swamps which isolate Rodd Peninsula. The dissected littoral strip of the Port Curtis district represents the western half of the old Lower Fitzroy basin, while relics of the eastern half occur in

Curtis and Facing Islands and Rodd Peninsula. The streams of the district—Larcom Vale Creek, the old Calliope-Boyne system, and the stream which entered Rodd Harbour—all made very acute angles on the downstream side with the betrunked Fitzroy. These were tributaries of the old rejuvenated pre-Fitzroy stream. The control exercised by rock strike is not apparent in the case of the old Rodd Bay stream, which excavated its basin out of granite. With approaching maturity, there has been a tendency for departure from the rock strike, manifested in the Fitzroy and its tributaries, which swing about in broad valleys. After reversal, conditions would have been favourable for the development of strike streams in the foundered portion of the Fitzroy basin.

SHORE-LINE TOPOGRAPHY.

The repetition of a certain definite pattern of topographic forms in the Keppel Bay-Curtis Island area and in the Rodd Bay-Rodd Peninsula area has been described. These features are similarly oriented, the units in relation to one another are similarly disposed, and the channel of The Narrows and Rodd Harbour and swamps are in alignment. It may reasonably be deduced that these features resulted from the operation of similar though not identical controls, particularly as the geological structure of each is different.

THE EVIDENCE OFFERED BY KEPPEL BAY.

It is generally agreed that the eastern shore-line has been drowned. The depth of silt deposited in betrunked stream channels is a valuable index of the magnitude of drowning. There is evidence of drowning in Keppel Bay. Mr. G. McLean has kindly supplied a section showing the materials passed through when he bored for water in the Fitzroy delta flats. The bore was put down between Balnagowan and the river. Mr. McLean penetrated to 120 feet, and passed through sand, black muds, and sand again at the bottom. At 98 feet, fragments of coral were obtained from the borings. At 120 feet, the valley floor had not been reached. This evidence indicates that marine conditions prevailed here, and that the corals were buried beneath the silt. A short distance south of Nankin Junction, in the Meadow Flats, in another boring, Mr. McLean passed through silts for 96 feet before striking solid rock.

On the south shore of the Fitzroy River a bore was put down on Casuârina Island; in the Queensland Mineral Index it is stated that "Murray's bore, sunk to a depth of about 233 feet, met with several beds of oil-bearing clays between 66 feet and the bottom. A bed of carbonaceous shale was penetrated at about 190 feet, some of the materials, on examination, being found to closely resemble the oil-bearing shales of Duaringa, The Narrows, Miriam Vale." These shales are freshwater deposits, and in The Narrows have been dredged up from the channel. Obviously, the freshwater beds were deposited before drowning; their presence indicates an interruption in the river cycle, when the river was dammed. The barrier was eventually removed, and the river excavated its channel in the lacustrine beds, to a depth, from the evidence of boring, of about 100 feet below present sea-level. In The Narrows belt the kerosene shales rise in places to about 100 feet above sea-level, so that it may be said the Fitzroy excavated a channel at least 200 feet deep in the lacustrine beds.

It is necessary to refer now to Mr. Dunstan's papers[7] dealing with the geological history of Keppel Bay. Mr. Dunstan considered that in early Tertiary time Curtis Island was joined with the mainland towards Cawarral, and the river had another outlet, represented by The Narrows. He stated: "The country to the west of the peninsula must have been low and swampy, and a vast quantity of sand and mud brought down by the river has accumulated there to form a series of sandstones and shales. While this filling-up process was going on, the river gradually wore away part of the peninsula, through which a second outlet to the sea was made, thus forming Curtis Island, and with the opening of the new channel the old one by degrees became closed." To the present writer it appears that infilling to the extent of over 200 feet could not have gone on while the river had an outlet through The Narrows channel as Mr. Dunstan suggested, for he stated it was only after the new outlet (the present one) was cut that the old Narrows Channel by degrees became closed. Mr. Dunstan regarded all the estuarine deposits at the Fitzroy mouth as being freshwater deposits. This is not the case. Later in his paper, Mr. Dunstan postulated an elevation of the freshwater beds of what must have been at least 150 feet, for it is stated that the Mackenzie Island sandstone (which is 147 feet high), and the smaller monadnock near by, are relics of this once extensive elevated sandy plain since removed by fluvio-marine denudation. A drowning of the shore-line was not postulated by Mr. Dunstan.

Accepting, for purposes of criticism, that the deposits at the Fitzroy mouth are all freshwater deposits, and originated as Mr. Dunstan suggested, these beds extend to a depth of more than 200 feet below the present sea-level, and have been elevated 150 feet. Prior to elevation they must have been at least 350 feet below sea-level—a position in which they could not possibly have been deposited in the manner outlined.

In a paper dealing with the phosphate-bearing rocks of the Rockhampton district, Mr. Dunstan published a sketch map showing a belt of turquoise-bearing slates, a belt of serpentine, and a belt of limestones and slates, trending N.W. and S.E., to which he referred in his paper dealing with the geological history of Keppel Bay. Discussing The Narrows, Mr. Dunstan stated: ". . . the river has trended away to the S.E. and followed the line of rocks which least resists its denuding action, has made a course for itself in the serpentine belt and flowed along the west of what is now Curtis Island and in the present channel of The Narrows." The belt of serpentine delineated by Mr. Dunstan is bounded on the west by a line from Yaamba or Canoona, across the Fitzroy in the vicinity of Broadmount, and slightly to the west of the Calliope River outcrop of serpentine and that of Calliope goldfield. The eastern bounding line is roughly parallel to this, and runs through Cawarral. The occurrence of serpentine in this belt is spasmodic, and the outcrops irregular. Mr. Dunstan clearly indicated that he inferred the presence of serpentine in The Narrows. From Yaamba to the mouth the Fitzroy River trends S.E., parallel to and in juxtaposition with the serpentinue belt on the west. The serpentine belt is characterised by the presence of a belt of high residuals; O'Connell Ridges, Mount Larcom, and Rundle Ranges occur in the Port Curtis area; and the Broadmount, Flat-top, Macdonald, and Berserker residuals reach Yaamba in the Lower Fitzroy basin. This rather suggests that the rocks of the serpentine belt resist erosion, and it is possible that this resistance is due to metamorphism effected by the intrusion of the serpentine. There is no reason to suppose that serpentine is relatively unresistant; indeed, at The Gap on the Fitzroy the contrary is demonstrated. Since in the lower sixty miles the Fitzroy flows on the west of the serpentine belt, and The Narrows channel occurs on the east of the belt (there is no evidence of the occurrence of serpentine here), the writer suggests that these channels are to be related to rock strike. At the present river mouth, the old pre-Fitzroy cut across the resistant serpentine belt during rejuvenescence, possibly owing to the presence of local less-resistant beds.

The writer believes that Mr. Dunstan's theory regarding the origin of Keppel Bay requires modification. As a preliminary discussion, presented over twenty years ago, it was a valuable contribution. It has been necessary to discuss these papers at length, to clarify the present writer's conclusions regarding the origin of Keppel Bay.

GENERAL NOTES ON THE SHORE-LINE.

It may be said that the Port Curtis-Keppel Bay shore-line has been drowned approximately at least 250 to 300 feet. The kerosene shales were deposited probably in mature valleys, and the basal beds of the series were but a few feet above sea-level. It is not known at what depth these basal beds occur, but beds are known at a depth of 233 feet below sea-level, so that 250 to 300 feet is approximately the magnitude of drowning that is known.

Relics of the former land extension occur in the Keppel Islands, Curtis and Facing Islands. No trace of other residuals are found here in the Barrier Reef Lagoon area. The course of the betrunked Fitzroy was not along the junction of the Devonian and a less-resistant formation. It is not unreasonable to assume, therefore, that, in the eastern drowned half of the Fitzroy basin, residuals of considerable elevation occurred, since there is no presumptive evidence that the eastern half of the Fitzroy basin was of low relief. A drowning to the extent of 300 feet does not adequately explain the absence of relics in the off-shore area. A movement of far greater magnitude is required. Such a movement may have been incurred by foundering—either by downwarping or faulting.

Curtis Island has been described, and the trend of the E. and W. axes of the island traced in the islands of Keppel Bay. The relief of the island may be described as hilly rather than rugged. The islands of Keppel Bay are of a different character. These are characteristically precipitous, and suggest the craggy summits of high residuals (typified in Mount Larcom, etc.), which have been drowned. This the writer suggests. The higher residuals of the district are 1,000 to 1,500 feet in elevation, on an average. If it is assumed that the Keppel Islands were residuals 1,200 feet high (above the present sea-level), then, since South Keppel Island is 500 feet high, a downthrow of about 700 feet is required to explain their present altitude. Such a movement, if it did occur, was differential, for Curtis and Facing Islands did not participate.

A description of the Mackenzie Island sandstone, considered to be an inlier of Upper Cretaceous sandstone in the Fitzroy delta, was given in the previous paper. This was considered to have been faulted down from at least the horizon of the sandstone occurring at Stanwell—a movement in which the Keppel residuals participated. The down-thrown area was thus of the nature of a block fault, bounded by a N.-S. plane on the west, more or less parallel to the present shore-line, and terminated on the south by a plane slightly north of east, parallel roughly to the southern shores of Keppel Bay. This movement did not involve the Fitzroy, which flowed about five miles to the south towards The Narrows. The Fitzroy was betrunked subsequently, when drowning to the extent of 250 to 300 feet occurred; the Keppel residuals were drowned and Keppel Bay was inaugurated.

It is suggested that Rodd Harbour originated in a similar manner; that this fault block was bounded by a N.-S. plane east of Curtis and Facing Islands and an E.-W. plane north of Rodd Peninsula. The throw of this block may have been greater than that of the Keppel block, for, after subsequent drowning, the residuals were completely submerged. Considerable infilling has since been effected in the Barrier Reef Lagoon area.

That the rocks of this area have been subjected to compressive loads, due to crustal readjustment in late geological time, is demonstrated by the fact that the Waterpark series, the Burrum Beds, and the Tertiary shales are strongly folded. Block faulting results from the imposition of torsional load, and has been demonstrated in South-eastern Australia.

PHYSIOGRAPHY IN RELATION TO THE BARRIER REEF AREA.

If one imagines the symmetrical restoration of the eastern half of the basin of the betrunked Fitzroy, the eastern rim of this basin will occur where the Capricorn and Bunker Groups of coral islets trend from N.W. to S.E. Also, if the trend of the Fitzroy through The Narrows, through Rodd Harbour, is prolonged south-eastward, such prolongation approximates to Curtis Channel, whose width is limited by the Breaksea Spit shoals on the south. It is suggested that these features are mutually related—a correlation independent of any particular mode of origin of the continental shelf.

From Breaksea Spit, the 100-fathom line trends parallel to the coast, distant about fifty miles. About eighteen miles north of the Fitzroy mouth, this line trends N.E., then N., attaining its greatest distance from the coast in the latitude of Cape Palmerston, where it is distant 160 miles across the normal to the shore-line. From this point the line trends N.W., roughly parallel to the coast. The Barrier Reef in this area comprises two groups of reefs, viz.:—(1) That which includes Lady Elliot, the Bunker, and Capricorn Groups of reefs, which trend N.W. and S.E. and are isolated from the northern reefs by the Capricorn Channel, and bounded on the south by the Curtis Channel, each trending from N.W. to S.E.; (2) the broad mass of the Swain Reefs, which trend to the N.W. The physiographic features of the mainland do not suggest that the Capricorn Channel and the Fitzroy River are related in any way. Rather, they suggest that the Capricorn Channel represents a broad river-basin, which before foundering was occupied by a stream which flowed more or less parallel to the Fitzroy.

In a joint report by Professor Richards and Mr. C. Hedley,[21] the following statement, with reference to the openings through the Barrier Reef, occurs:—"These have been regarded by Jukes, Saville Kent, and others as marking old entrances to the sea, of the present coastal rivers. This hypothesis does not bear a close scrutiny, for from the Admiralty charts no causal connection may be seen between these openings and the present rivers, nor may one find any evidence of defined valleys through the lagoon area corresponding in any way to the coastal rivers."

In relating the openings through the Barrier Reef to the present streams, writers have neglected to study the evolution of the modern river systems, and sought to relate features which post-date the Barrier Reef inauguration, with that feature. Naturally such correlations do not survive investigation. Rarely are the trends of the present rivers, which once flowed in the foundered lagoon area, preserved in that part, but in the Port Curtis district the trend of the betrunked Fitzroy may be followed through the Barrier Reef.

The Mulgrave River is an insequent stream, which once had its outlet to the sea in Trinity Inlet at Cairns. The modern stream enters the sea about twenty miles to the south. There is no justification for relating Flora Pass, which antedates the present Mulgrave Outlet, with that feature, but it is probable that Trinity Opening through the reef to the north marks the foundered Mulgrave Valley.

Various writers have commented on the smallness of the delta deposits at the Burdekin mouth. This is presumptive evidence of the youthfulness of this embouchure, and no corresponding opening through the reef could be expected.

The streams of the Queensland littoral, from the Port Curtis district northwards, are considered to have evolved from a more or less meridional drainage scheme by the development of approximately E.-W.-flowing lateral streams (''meridional'' in this case signifying streams flowing in the N.W. to N.E. and S.E. to S.W. quadrants). This is perhaps best demonstrated in the Fitzroy, and is in accord with the conclusions of Messrs. Hedley, Taylor, and Danes, regarding the North Queensland rivers, and was suggested by the first two writers jointly, for the rivers of New South Wales.

In the foundered continental shelf area the drainage was similar. This is evidenced by the occurrence of reef belts separated by passages, which in the southern Barrier Reef area trend N.W. to S.E., and in the northern area trend N.E. and S.W. The foundering of the continental shelf occurred in late Tertiary or Pleistocene time. The streams occupied relatively deep valleys, and had in many cases been modified in the manner indicated; however, none of the major openings through the reef trend in an E.W. direction, for the dominant residuals trended meridionally and it was upon these that the reef ramparts were raised. (The trends of the reef openings are clearly indicated in the Australia Pilot, vol. iii.)

Professor Richards and Mr. Hedley further stated: ''We prefer to associate the openings with the coastal valleys of the foundered strip on the edge of which now exists the Great Barrier Reef.'' With this the present writer agrees, but would amplify the expression by adding that certain of the openings through the reef mark the foundered portions of certain of the present stream basins.

CONCLUSION.

THE EVOLUTION OF THE FITZROY RIVER.

Having concluded the investigation of the Lower Fitzroy River, it is perhaps desirable to summarise the conclusions adopted. The features of the Port Curtis district offer additional evidence supporting the writer's conclusions regarding the Fitzroy evolution, presented in the earlier paper.

The Lower Fitzroy is an obsequent stream which at one time flowed from the former land extension beyond Curtis Channel towards Broad Sound, which is probably a relic of the valley of this old stream, to the N.W. In early Tertiary time this stream was rejuvenated, and under comparatively quiescent conditions excavated a broad valley. Many of the tributaries of this old stream are preserved in the lower basin and in the Port Curtis district. Later, arising from some cause, probably differential movement in the rising area, the stream was reversed and flowed eastward (as contrasted with westward) still along the strike towards S.E. The new divide approximated to the present low hills which divide the Fitzroy waters from those of Broad Sound. As a result of the more vigorous movements of the Kosciusko epoch, the eastern land extension in this area was faulted down, probably differentially, in tilt-blocks. The river continued to flow through The Narrows channel. An interruption in the cycle resulted in the damming of the river and the deposition of the kerosene shales in the stream basins. The origin and nature of this barrier are not known; possibly, it was a direct result of the foundering. The barrier was subsequently removed and the stream eroded the lacustrine beds to a considerable depth. Then followed a drowning of the shore-line to the extent of 200 to 300 feet, when the Fitzroy was betrunked. The Keppel residuals were drowned, Great Keppel Bay was inaugurated, and The Narrows channel became vestigial. As the river cycle advanced, the expansion of an E.W.-flowing tributary resulted in the breaching of the lateral western valley residuals at The Gap, when capture of the adjacent S.E.-N.W. stream followed. Later, a negative movement of the sea of fifteen feet approximately occurred, and this resulted in the reclamation of the bay head silts of Great Keppel Bay, and these form the present Fitzroy delta lands. Curtis Channel and the Capricorn-Bunker Groups of coral islets, the writer concludes, mark respectively the old river channel and the eastern rim of the foundered Fitzroy basin.

While the direction of flow of the Lower Fitzroy and certain streams of the Port Curtis district may be correlated with rock strike, the direction of flow of the latter streams was opposite to that of the Fitzroy in the betrunked area. In the case of the abnormal streams of the Lower Fitzroy basin, which rise in the resistant belt of the Berserker series mainly, no relation to strike or structural features may be observed. All of these streams belong to the period of rejuvenescence when the drainage was to N.W., and have persisted after reversal.

If the trend of the Lower Fitzroy is prolonged beyond Yaamba by a line, this line will isolate the Broad Sound Peninsula. Such a line, too, follows a broad gap, now a divide between the Broad Sound and Fitzroy waters. Through this gap the Northern Railway passes to Mackay, rising only to 280 feet at Marlborough. Hedlow Creek rises in the Berserker residuals and flows N.W., joining Alligator Creek by way of lakes and swampy depressions. Whether the Fitzroy flowed by way of Lower Alligator Creek and Herbert River to Broad Sound, receiving Hedlow Creek, or whether the river flowed through the railway gap to the Styx River depression, receiving the Gogango-Marlborough Creek section of present stream, to be joined by Herbert River in Broad Sound, are problems which may be solved by future field investigation in the Broad Sound area.

Tentatively the writer suggests the latter possibility. The divide between the Styx River and the Fitzroy waters has been shown by Mr. Rands[23] to be an extremely youthful feature. He stated: "The divide between the Fitzroy and Broad Sound waters consists of a tableland of about five miles in breadth covered with a coarse conglomerate, which is probably of Post-Tertiary age. This conglomerate . . . consists of coarse pebbles of shale, sandstone, quartzite, and quartz. It overlies the Permo-Carboniferous rocks, which can be seen in the beds of some of the deepest gullies. Conglomerates of probably the same age are to be seen overlying the Coal Measures on the margins of the Marine Plains in the neighbourhood of Foyle Park and again overlying the Permo-Carboniferous rocks near Bridge Creek, Wilangi."

Dr. Marks, in his Presidential Address, quoted the fall of the Fitzroy from Boolburra to the mouth as being under one foot per mile, "although it includes the supposed rejuvenated portion." The present writer prefers to say that for more than 100 miles above Yaamba (where Alligator Creek joins the river) the fall of the Fitzroy is over twelve inches per mile. Below Yaamba, in the lower sixty miles, the fall is between one and two inches per mile. From north of Gogango, in the Fitzroy two distinct basins are apparent; it is the lower portion of the stream which is considered to be the obsequent stream. The river through The Gap residuals is not considered to be a rejuvenated portion.

These conclusions regarding the Fitzroy River are not in agreement with the tentative suggestions of earlier writers, who did not have an opportunity of investigating the stream in the field.

Professor Taylor[20] suggested that the Fitzroy between Woodville and Boolburra was subsequent. He regarded The Gap residuals as the divide between this subsequent stream and the Fitzroy, a youthful stream apparently developed as a consequent in the rising plateau. He regarded the Calliope River as having been developed in its present form, and that the Boyne formerly formed part of the headwater drainage of the Condamine. The writer's interpretation has already been given: The asymmetric streams at the head of the Boyne are regarded as having resulted from the expansion of the Boyne itself, assisted probably by faulting, and that this stream was developed as a tributary to the old N.W.-flowing pre-Fitzroy and formerly was the Upper Calliope.

Mr. Hedley[24] had pointed out that the Fitzroy River, one of the longest of Eastern Australia, occurs opposite the broadest expanse of the continental shelf. "Protected by their submarine buttress the Fitzroy and Burdekin more nearly represent primitive radial drainage than any other Australian stream flowing into the Pacific." . . . "The fate that apparently overtook other streams during the crumpling of the coast, of being broken in the middle and reversed, threatened them also. But the partial protection of the submarine buttress rendered the attack less severe than it was either north or south. So these rivers survived as radials, but not without a hard struggle." The evidence, the present writer concludes, does not support Mr. Hedley's suggestions. On the contrary it is strongly opposed.

Dr. Danes[25] expressed disagreement with Mr. Hedley's suggestions regarding the Fitzroy River. With reference to this stream he stated: "I maintain my theory that the rivers which from all parts join to form the present Fitzroy system formerly formed one or several more or less connected lake basins independent of the Pacific drainage but also of any western river system.'' Dr. Danes did not suggest an evolutionary scheme for the Fitzroy, and, in so far as his suggestion involves the Lower Fitzroy, the writer concludes that it is a possible explanation. This stream has excavated a basin 2,000 feet deep. Undoubtedly the base-level of the pre-Fitzroy which flowed beyond Broad Sound approximated to sea-level, for when reversed the stream was intrenched in a broad valley in the plateau, and the lateral Gap residuals which were subsequently breached existed. The Gogango-Marlborough section of the present Fitzroy was probably dammed by the movement which reversed the Fitzroy, and lacustrine conditions imposed until the breaching of The Gap residuals by the tributary of the Fitzroy.

The material of the Cretaceous Sandstone occurring in the Lower Fitzroy basin appears to have been derived from the S.E. As the Cretaceous sea-bottom became dry land, the pre-Fitzroy penetrated further towards the N.W. beyond Broad Sound. As elevation proceeded, this stream was rejuvenated; since on the Admiralty charts no opening through the Barrier Reef corresponding to such a stream is indicated it is possible that the pre-Fitzroy emptied into a basin, or area of comparative still-stand in the rising area, beyond Broad Sound. This, however, is merely conjecture, for the evidence, if it had not been removed by subsequent erosion, lies buried beneath a mantle of infilling and the sea. However the stream was inaugurated, the writer concludes that there is decisive evidence of an old N.W.-flowing pre-Fitzroy stream of which Broad Sound is a relic.

[The writer's previous paper dealing with the Lower Fitzroy Basin was criticised, amongst others, by Dr. E. O. Marks in his Presidential Address delivered before the Royal Society of Queensland, 1924.

Dr. Marks was unaware that the investigation of the Lower Fitzroy River awaited completion and the criticism was therefore somewhat inopportune. On page 36 of the ''Physiography of the Lower Fitzroy Basin'' an error occurs. The words in brackets ''(quoted by Professor David)'' should be ''(quoted from Professor David).'' This error was obvious from the context, but Dr. Marks chose to impute inaccuracy in another direction. It is only fair to point out that the critic himself inserted the word ''down'' after ''thrown'' in his citation. For the rest, Dr. Marks's criticism is based on his own assertions, which appear to display unacquaintance with the related subject matter. The assertion that the present writer relied on the interpretations of Professors David and Taylor is inaccurate. Dr. Marks stated: "On page 36 he" (Jardine) "says 'physiographically there is little evidence in this area indicating a fault shore-line as it undoubtedly is' and quotes Professor David as the authority for this faulting." This is incorrect. The description quoted referred specifically to the shore-line area. The shoreline, while physiographically not a typical fault shore-line, was undoubtedly such. Faulting was postulated from the evidence of the Mackenzie Island sandstone. Professor David's opinion was corroborative and was quoted. Professor David expressed conviction based on probable evidence, which was simply an opinion, and was so regarded.

The value of fair criticism cannot be over-estimated and is welcomed by the writer, for our knowledge increases by the gradual accumulation of interpretations of field evidence, until finally the "physiographic background to the geological facts" emerges from the haze of uncertainty.]

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THE DEVELOPMENT AND SIGNIFICANCE OF BENCHES IN THE LITTORAL OF EASTERN AUSTRALIA.

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(Plates XVIII.-XXII. and Eight Text Figures.)

No. 13.

INTRODUCTORY.

The processes of marine planation are but imperfectly understood, for these operate largely beyond the range of observation and little is known of the dynamic effects of wave and current actions at depth. Determinative controls, too, are inconstant, and as a result interpretations are largely conjectural. Certain features, however, originate within the zone of tidal action and are discussed in this paper.

The rough-hewing in shore-line sculpture is effected by waves —especially the storm-waves—which deliver disruptive impacts, where conditions are favourable, directly against the land. In the case of an indented shore-line with the land steep-to, the headlands become notched and there are developed benches (marine-abrasion platforms, wave-cut terraces), which later in the cycle become obscured. On subsequent pages, benches at various localities in Eastern Australia are briefly described, their development and significance discussed.

PREVIOUS LITERATURE AND ACKNOWLEDGMENTS.

The presence of benches along the eastern seaboard of Australia has been commented on by various writers. The best development of these occurs in the Triassic and Permo-Carboniferous sediments north and south of Sydney, N.S.W., and it is to the remarkable platforms of this locality that attention has been directed largely, in literature.

The earliest description of these benches is that by Professor J. D. Dana,[1] who was a member of the scientific staff of the United States Exploring Expedition under the command of Captain Wilkes, which arrived in Sydney in 1839.

In 1916 Mr. E. C. Andrews[2] pointed out that in addition to the broad platforms awash at high tide ". . . certain of the more vertical cliffs in the hard sandstone around Sydney overlook rock platforms lying above high-water mark. . . . The platforms are at such heights that heavy storm-waves could not have carved them during the period which the sea has stood at its present level, seeing that the action is not due to benching but to active truncation of rocks dipping gently inland, and moreover a low cliff of submarine erosion forms the seaward aspect of the bench or terrace. The present position of these benches of marine erosion can be explained satisfactorily only upon the assumption of a recent and slight emergence of the land. . . ."

In a paper read before the Royal Society of N.S.W., Mr. C. Hedley[3] described the development of marine terraces in Bluefish Bay, and at Wyargine Point three miles south-west of the former. From the evidence of the terraces he deduced a movement of differential elevation, twenty-five to thirty feet at Bluefish Bay and ten feet at Wyargine Point.

Elevated benches have been described on islands off the Queensland coast by various writers. References to these will be found elsewhere in this paper.

This investigation was suggested to the writer by Professor W. R. Browne, who in the course of conversation pointed out certain curious features of the bench at Long Reef, N.S.W. The writer wishes to acknowledge indebtedness to the Great Barrier Reef Committee which generously provided transport facilities, and to Mr. I. M. Cowlishaw, B.E., Engineer for Lighthouses, Queensland, who courteously invited the writer to travel on the s.s. "Karuah."

PRELIMINARY GENERAL DISCUSSION.

Benches occurring between tide-levels are considered by certain investigators in Australia to afford evidence of elevation. These are regarded as having been developed at a depth and subsequently elevated.

Mr. E. C. Andrews's interpretation was not in accord with this view, for he considered that it was only from the evidence of platforms which are now found beyond the reach of high tides and storm-waves that elevation may be deduced, although it is evident, by implication, that this writer concluded that benches may be developed on any horizon below the storm-wave zone, for, in describing the elevated platforms, he mentioned that on their seaward side these are bounded by low cliffs of submarine erosion.

It is clear that factors such as meteorological variability, contour of foreshore and submarine slope, and geological conditions, are determinative controls influencing marine erosion. Efforts have been made by investigators, particularly in those countries where protection of foreshores is of vital importance, to study wave processes generally by constructing models of land forms and submitting these to the action of artificially produced waves, but invariably it has been found that conclusions adopted from these experimental results have been unreliable. Harbour works are constantly being damaged or demolished by wave-action, and it is mainly through the knowledge gained by experience that hydraulic engineers are able to design, eventually, efficient structures.

It is evident that conclusions adopted regarding benches must have a firmer basis of truth than those suggested from theoretical or mathematical considerations alone.

BENCHES IN SEDIMENTARY ROCKS.

(*a*) Long Reef, N.S.W.

At Long Reef (five and a-half miles north of Port Jackson), one of the finest platforms on the coast occurs. This is a wedge-shaped projection about 400 paces long, and 400 paces broad at its base (excluding the fringing benches), which is prolonged for 200 yards in a covered rock-reef. The geological structure and profile are illustrated in Fig. 1, which is diagrammatic. The general level of the bench is two to three feet below the level of high-water springs. The outcropping rocks are mainly chocolate

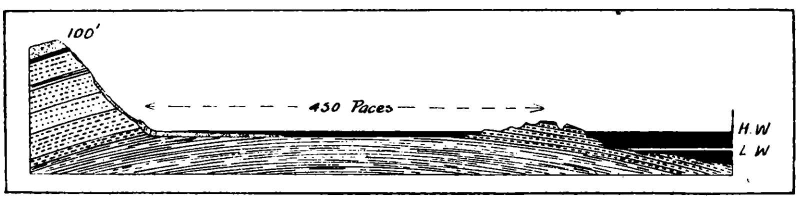

Fig. 1.—The Bench at Long Reef, N.S.W.

shales (Narrabeen Beds). On the seaward side, a dissected outlier of green and reddish sandstone with intercalated narrow bands of shale occurs, which is elevated about fifteen feet above the general platform level. On the inner side, the descent to the platform is by a series of terraces, due to the differential erosion of the sandstone and shale, while on the outer or seaward side the descent is more abrupt and vertical. The beds of the outlier dip gently to N.E. at 5°. On the seaward side of the outlier, a small cliff three to four feet high bounds the main platform and overlooks a smaller bench which slopes gently below low-water level.

The main platform is overlooked by a cliff 100 feet high, mainly of Hawkesbury sandstone and shale. At the cliff-base the strata dip W. at 14°. The projection is thus a gently warped anticline whose crest has been eroded.

Tabular blocks of reddish and greenish sandstone occur scattered over the surface of the platform. On the north side these blocks are sparsely distributed, but on the south side they have accumulated and lie piled on the platform as overlapping plates. The blocks had their origin in the marine erosion of the outlier and occur in places *in situ*. The process of their formation is clearly shown on the inner side of the outlier, which is strongly undercut. Isolated earth pillars also occur. The reason for the distribution of the blocks is clearly indicated in the cliff profiles.

On its eastern aspect, the cliff is much subdued and has weathered back to a fairly gentle débris-covered slope. The absence of marine erosion at the cliff-base is indicated by the accumulation of beach material and the presence of a broad sand-spit about 200 paces long, directed out on to the platform, but recurved to the north. The northern cliff profile is one of late youth. The slope is steeper, but material is accumulating along the cliff-foot. The southern profile is an extremely youthful one. Here the cliff is vertical and beach material is absent. It is evident that the main wave-attack is directed from the south, and it is for this reason the outlier is preserved on the outer or eastern margin of the bench.

(*b*) Headland North of Edward's Beach, Middle Harbour, Port Jackson.

Fig. 2 illustrates the bench profiles in the headland at the northern end of Edward's Beach. These occur in the massive sandstones of the Hawkesbury Series. The beds, which dip gently westward, have a vertical system of joint planes strongly developed. Here, platforms occur on three horizons. The main bench is developed three to four feet above low-water level and is about thirty paces broad. It is terminated on the seaward side by a

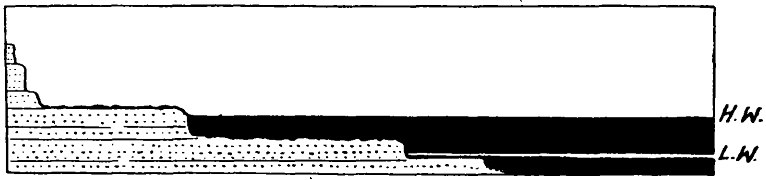

Fig. 2.—Benches in Headland, north of Edward's Beach, Middle Harbour, N.S.W.

small cliff two to three feet high, which overlooks a low-level platform. The latter slopes gently below low-tide level. A third platform occurs slightly above high-water level. This bench is terminated on the seaward side by a small cliff, which is retreating before the present wave-attack. On the surface of this bench, blocks which have fallen from the overlooking cliff, here thirty to forty feet high, are accumulating. The cliff is a more or less subdued feature, indicating that at the present-time subaerial erosion dominates marine erosion.

(*c*) Ben Buckler, Bondi.

Benches are developed on two horizons in the Hawkesbury Series in this locality (Fig. 3). The surface of the low-level platform is slightly convex and slopes gently below the low-tide level. The upper bench occurs slightly above the high-water level

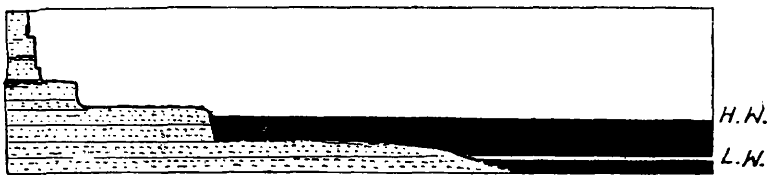

Fig. 3.—Benches at Bondi, N.S.W.

and is bounded on the seaward side by a small cliff five to six feet high, which is retreating. The coast-line cliff is about eighty feet high, and towards its base a broad ledge occurs which may not be an elevated bench.

(In the Port Jackson and Broken Bay areas, the occurrence of ledges, both broad and narrow, at various elevations, are marked features of the valley sections. These are considered by some investigators to indicate pauses during uplift, but the horizons on which the ledges occur are so inconstant, that the majority must be assigned to the action of subaerial agents in effecting differential erosion, which results in stripping.)

(*d*) South Coast Area, N.S.W.

Well-developed benches in the Permo-Carboniferous sediments occur abundantly in the South Coast area of N.S.W. Since these exhibit similar features to the foregoing, they are not here described.

(*e*) Mackenzie Island, Central Queensland.

Elsewhere,[4] the occurrence of a fluvio-marine monadnock of what is probably Upper Cretaceous sandstone, on Mackenzie Island, has been described. Marine cliffs and benches, the latter almost obscured by silt, occur distant about 100 yards from the shore-line and 15 to 20 feet above the present high-water level.

BENCHING IN METAMORPHIC ROCKS.

(*a*) Archer Point ($8\frac{1}{2}$ Miles South of Cooktown).

The rocks of this locality consist mainly of coarse and fine grained quartzites and banded slates, all of which are traversed by quartz veins. The rocks, which have been strongly folded and crumpled, are fractured by several systems of joint planes. Relatively softer bands occur intercalated with harder bands. The rock strike varies between E. 30° N. and N. 35° W., and the dip from 82° S.E. to 75° N.E.

In this locality there is an inconstant development of benches. The coast-line cliffs rise to 200 feet and are broken by shallow indentations. Benches occur in some of the projections north of Archer Point.

Fig. 4*a* illustrates a relic of a high-level bench. The overlooking cliff is twenty to fifty feet high and débris-covered. The cliff-foot is fringed by detrital material which is covered by vegetation and bounded by a small coral shingle embankment, which has been piled up by the action of storm-waves. The platform is fragmental, but the surface may be traced sloping seaward from eight feet to three to four feet above high-water level. The rocks are homogeneal.

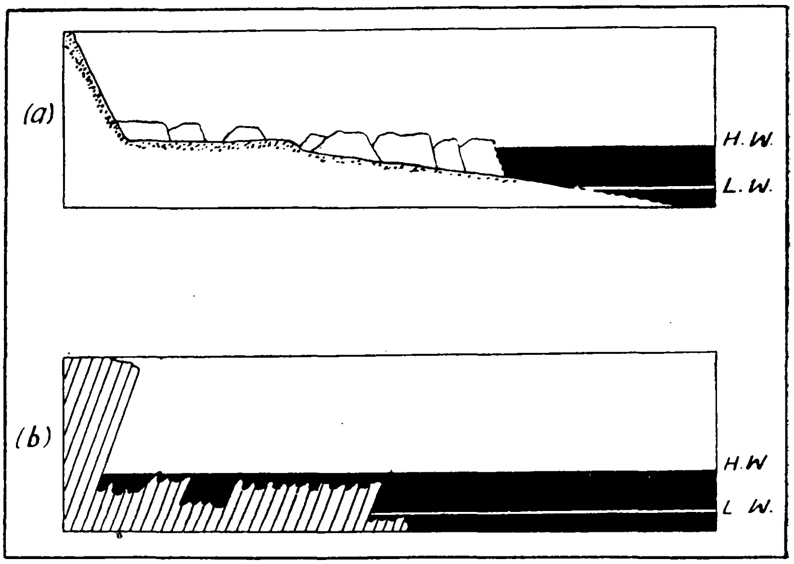

Fig. 4.—Benches at Archer Point, south of Cooktown, Queensland.

Fig. 4*b* illustrates a bench cut about two feet below the level of high water. The waves have eroded across the planes of secondary cleavage, and the differential erosion of relatively hard and soft bands has produced a rugged bench surface.

(*b*) North Keppel Island.

The rocks of this island, considered to be Devonian in age, comprise sandstones, quartzites, and phyllitic rocks, which towards the N.E. strike W. 30° N. and dip N.E. at 15°. In the cliff sections on the N.E. side of the island, the rocks appear to be almost horizontal. Here, benches are developed on a horizon slightly above high-water level, but not beyond the zone of storm-wave activity. (See Plate III.)

BENCHING IN GRANITIC ROCKS.

(*a*) Eborac Island.

A description of this island has been given jointly by Professor Richards and Mr. C. Hedley,[5] with an analysis of the quartz felspar porphyry of which the island is composed. "On Eborac Island the porphyry has a highly developed platy-jointing arranged vertically for the most part, and separated by 3-4 inches only. These joints strike N. and S., and are intersected by other vertical joints, not so regular or closely associated and striking more or less E. and W. A third system of joints is more or less horizontal, but dips a little to the south. This results in the development of 'platforms'."

Measurements by the writer indicated that the major joint planes strike E. 40° N. and dip at 85° N.E. This system is intersected by another striking roughly N.W. and S.E., as well as by a third nearly horizontal system dipping N.E. As the joint planes are bent, particularly towards the S.E. end of the island, the differences of the recorded measurements may be reconciled. In places, the horizontal joint planes are absent. Here merely rugged and broken ledges occur.

Plate IV. illustrates a bench on the northern side of the island. This is developed at about half-tide level along the horizontal joint plane. The effect of the vertical jointing is pronounced.

(*b*) Albany Rock.

Albany Rock, a small island 84 feet high, distant about 1¾ miles from the S.E. end of Albany Island, is composed also of porphyry. The island is capped by a small outlier of gently dipping sandstone, now considerably undercut. On page 19 of the paper by Professor Richards and Mr. C. Hedley[5] it is stated that "Albany Id., Mai Islet, Albany Rock, and the Brothers Islands some few miles to the east, strongly suggest from their contours that the nature and position of the platforms around them that they have been subjected to a comparatively recent emergence. So variable as to size and time, however, are the tides in this region that it is difficult from a short period of observation to give a definite opinion on such a matter."

From the S.E. end of Albany Rock a rocky ledge extends towards the S.E. for nearly 200 yards, and this becomes covered at high water. On the E. and N.W. sides of the island, benches are well developed on two horizons.

The systems of joint planes developed in the porphyry of this island vary somewhat, striking N. 10° E. and S. 30° E., or thereabouts, the former dipping at 20° N.W. It is this gently dipping system of joint planes which has controlled bench development (Fig. 5). The upper bench occurs five to six feet above the level of

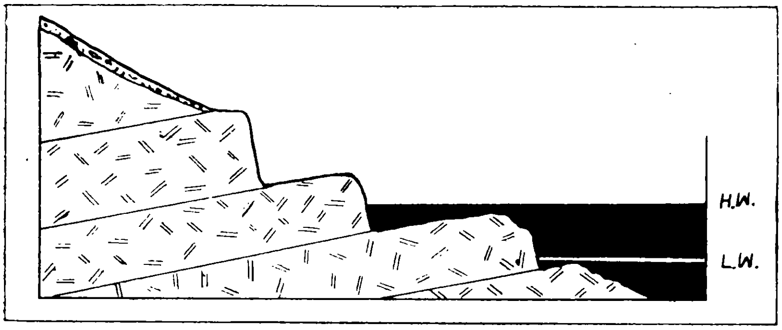

Fig. 5.—Benches, Albany Rock, North Queensland.

high water and the lower two to three feet below the level of high water. The latter is bounded on the seaward side by a small cliff overlooking a bench three or four yards broad, which falls below the level of low water. The upper tidal limit was determined from the rock appearance.

BENCHING IN VOLCANIC ROCKS.

1. Lava Flows.

(*a*) *Darnley Island.*

In another paper of this series of Transactions, the writer will describe the development of benches in the basaltic flows and tuffs of Darnley Island.

(*b*) *Bramble Cay.*

The volcanic nucleus of this reef consists of a series of flows preserved in a small crescentic outcrop. On the north side of the crescent and distant but a few yards, a large isolated block occurs in which the flows strike W. 36° N. and dip 15° S.W. On the S.E. aspect of this block a bench is developed along what is apparently a junction plane, ten feet above low-water springs. The bench is bounded by a cliff, which overlooks the coral conglomerate flats of the reef. The bench is two feet below high-water level (Fig. 6).

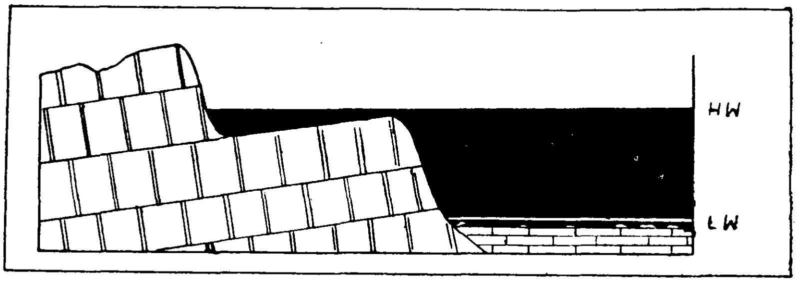

Fig. 6.—Bench, Bramble Cay, Torres Strait.

2. TUFFS.

Black Rocks.

A small group of rocks, which become covered during high water, lie about three miles south-west of Bramble Cay and are known as the Black Rocks. The beds are tuffs having a banded structure of coarse and fine grained material. The dip is towards the S.W. at 15°. On the N. side, benches, which are the homologues of the small secondary benches which elsewhere appear at low-water level bounding the main benches, are developed (Fig. 7).

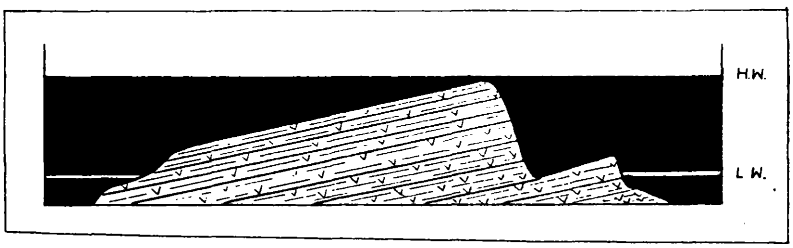

Fig. 7.—Bench, Black Rocks, Torres Strait.

BENCHING IN NEW ZEALAND.

Benches have been figured and described by various New Zealand investigators. Those occurring between the tidal limits are not considered to afford evidence of shore-line emergence. Figure 8 (*a*) and (*b*) are drawn after Professor Park,[6] who stated: "The manner in which marine erosion is effected varies with the mood of the sea. In the normal mood, which is tranquil or semi-tranquil, the sea, by constant rise and fall of tide, alternately covers and uncovers a marginal strip of land that in time becomes worn down into a bench, that slopes from low-water to high-water mark" (Fig. 8 (*a*)). "Where the rocks are soft, the bench may be worn into a flat platform, lying a foot or two above low-water mark" (Fig. 8 (*b*)).

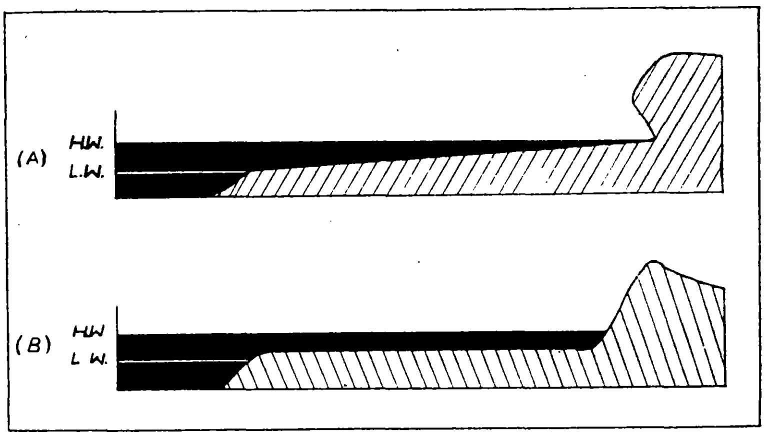

Fig. 8.—(A) Marine Erosion of Sloping Bench in Auckland Harbour.
(B) Flat Bench Excavated in Chalky Marls, Amuri Bluff, N.Z.

[*After Professor Park.*]

Dana[1] described and illustrated a bench occurring in an unstratified argillaceous sand-rock on an island, called the "Old Hat," in the Bay of Islands, N.Z.: "The shore shelf stands about five feet above low water . . . the platform encircling it . . . forming a broad brim to a rude conical crown. The water in these cases has worn away the cliffs leaving the basement untouched."

WAVE ACTION—THEORETICAL CONSIDERATIONS.

Before discussing the evidence afforded by the foregoing examples, it is desirable to briefly consider certain theoretical aspects of wave-activity. A mathematical discussion of this subject will be found in the Encyclopædia Britannica; more general accounts are given in various text-books including those of Matthews,[7] Cunningham,[8] Latham.[9] The subject of waves and tides is one that has attracted innumerable investigators, and an excellent summary of results, from the geological aspect, is that by Johnson.[10] These authorities have been drawn on for the following summary.

Energy imparted by the wind causes the surface of the sea to rise and fall rhythmically in the form of oscillatory waves. The wave-form advances but the water particles merely rotate in circular orbits. As the wave approaches shallow water, its height and length increase, but with constantly diminishing volume of water the new wave-form is incompletely developed; deformation occurs and the wave-crest curls over into the preceding trough, forming surf. Waves break approximately when the wave-height is equal to the depth of water. The velocities of the water particles in an oscillatory wave diminish in geometrical progression as depth increases in arithmetical progression. At a depth of one wave-length below the crest, the velocity is $\frac{1}{535}$ of that in the crest. At a depth of two wave-lengths, the velocity is $\frac{1}{286690}$ of that in the crest. Translatory waves arise as a result of the breaking of oscillatory waves. (This is not the sole mode of origin.) In these, there is only a small decrease in velocity of water particles below the crest.

Where a coast-line is steep-to, the waves act directly on the cliff-faces, which are of the nature of barriers, and the wave energy is dissipated largely in disrupting the material of the obstacle. Clearly, the maximum damage is effected in the zone of the wave-crests. The energy of the translatory waves (largely), and currents which arise as secondary effects, are dissipated in transporting, comminuting, and redistributing the material disrupted by the large oscillatory waves and the translatory waves which exercise a similar effect. The zone of attack is alternately raised and lowered by the tidal waves. Shoaling waters act as a protecting bulwark against the larger waves, but in such waters the tidal wave increases and thus allows ingress to the cliffs of the larger waves during the periods of high water.

ANALYSIS AND CORRELATION OF EVIDENCE.

Benches occurring along the eastern shore-line may be divided into three groups, viz.:—(*a*) Those which occur on horizons between high-water level and fifteen feet or so above this level; (*b*) those developed between high and low tide-levels; (*c*) smaller benches occurring on the horizon of low-water level, which for the moment may be neglected.

At Narrabeen, a relic of a high-level bench occurs as a dissected outlier on the outer aspect of the present bench, and is being rapidly deplaned with the production of a broad level bench two or three feet below high-water level. At the northern end of Edward's Beach, at Ben Buckler, at Albany Rock, the high-level platforms are bounded on their seaward sides by small cliffs of marine erosion, which are retreating before the wave-attack. Resulting from this deplanation, also, benches are being developed which lie between high and low water levels. At Archer Point there are traces of high-level benches very much dissected, and elsewhere, in the same locality, benches are being developed between the tide-levels. At Mackenzie Island and on the mainland at the mouth of the Fitzroy River, benches occur 10 to 15 feet above high-water level, distant about 100 yards from the shore-line, while in Keppel Bay more or less well-developed benches are to be seen between tide-levels. At Darnley Island fine examples occur three feet or so below high-water level, in the tuffs of Treacherous Bay. Elsewhere on the island, traces of high-level benches occur in the lava flows, which are more resistant to erosion.

The presence of a strand-line of fairly uniform elevation, marked by the occurrence of elevated beach materials with remains of marine organisms, marine-cut cliffs now distant from the shore-line, marine caves elevated above the zone of wave-action, clearly indicates that in Eastern Australia, in late geological time, the sea-level relative to the land stood ten to twenty feet higher than it does at the present time. It is clear that the benches which occur above the present high-water level, beyond the zone of present wave-activity, were developed in the previous cycle when the sea-level was ten to twenty feet higher, and, from their positions, these must have been developed between the tide-levels of the period. Again, in the various localities marine deplanation of the present cycle is causing the elevated benches to disappear and new ones to appear between the present-day tide-levels.

The conclusion that benches are developed originally at a depth is not substantiated by the evidence of field occurrence, which indicates that the development occurs between tide-levels.

In localities where benches are finely developed it may be assumed that conditions are most favourable for observation and abnormalities are least likely to occur. Such type localities occur at Long Reef and Darnley Island (Treacherous Bay). Here, broad level benches occur but a few feet below high-water level and in each case the bench is bounded on the seaward side by a small cliff a few feet high, overlooking a very much narrower bench, which slopes below low-water level. Under favourable conditions of geological structure, these smaller benches invariably bound the main benches on their seaward side, as at the headland north of Edward's Beach and Albany Island, etc. It is evident that there is a concomitant development of benches in these localities, the main one approximating to the upper tidal limit and the secondary approximating to the lower tidal limit. The most powerful oscillatory waves reach the shore when the water is deepest, i.e. during the high-water periods, and it is the more powerful waves which effect the notching of the headland. During the periods of high and low water the surface of the sea is comparatively quiescent, but during the flow and ebb it becomes rougher. A consideration of the tidal curve for any locality demonstrates that the tidal gradient is not steep at the periods approximating to the times of high and low water. These are periods of relative still-stand in the level of the sea against the shore. The wave-crests are elevated somewhat above the sea-level, and thus the main erosional effects are exhibited in the upper tidal zone. The bench surface is the plane above which material has been disrupted and removed. As the trough of the tidal wave approaches, the bench, carved by the powerful waves which reach the shore during the high-water periods, becomes uncovered, and as the period of low water is reached the sea abates somewhat. The foreshore, however, is still subjected to erosional effects but of a much milder character. Since the water is shallower, the larger oscillatory waves break. The foreshore still acts as a barrier to the small oscillatory and translatory waves, whose attack results in the development of a much smaller bench on the seaward aspect of the main platform, about the horizon of low water.

THE INFLUENCE OF GEOLOGICAL CONDITIONS.

The definite control exercised by geological conditions in influencing the development of benches is clearly demonstrated in the examples cited.

The most perfect examples are found in the sedimentary rocks when these are fairly soft, or contain relatively hard and soft intercalated beds, in which the inclination of the strata approximates to horizontal. In contorted and steeply dipping metamorphic sedimentary rocks (as at Archer Point), conditions are not so favourable. Benches are developed, but these are fragmentary and inconstant features.

The stratified tuffs of Darnley Island and the Black Rocks are favourable mediums for the development of benches, the conditions approximating to those of a gently dipping, fairly soft, sedimentary rock. On the opposite side of Darnley Island, benches are poorly developed in the lava flows; when such do occur, they are developed in this locality along the junction planes of successive flows, which are almost horizontal. In the case of granitic rocks, benches are developed only when these are fractured by one or more systems of joint planes, one of which is horizontal or nearly so. The waves seek out lines of weakness, and where such occur it is along these planes that the wave-pressures effect disruptive disintegration, although such planes may not be the horizon of most effective wave-attack. This is the case at Albany Rock and Eborac Island. At Cape Grafton the granite is homogeneal and rarely strongly jointed. The headland has weathered into that rounded, smooth form so characteristic of granite, without a trace of notching. In the shallow water about the bases of the cliffs, accumulations of fallen boulders are occasionally met with.

THE EVOLUTION OF THE BENCH.

The development of the bench in its first stages has been considered. As the bench is broadened the power of the wave decreases until at a certain width wave-attack ceases on the cliffs. Subaerial erosion causes the cliff to retreat to a gentle slope and the bench at the cliff-foot becomes débris-strewn and beach material accumulates (as at Long Reef). This is but a temporary accumulation, for, on the seaward side of the bench, the secondary bench at low-tide level is being constantly enlarged. The surface of the main bench, too, is continually being lowered, for during the high-water periods the waves and currents are provided with graving tools on the débris-strewn platform. The cumulative result is the development of a bench on the horizon of the secondary or low-level one. This bench, too, is slowly lowered by the continuous abrasion it is subjected to by the comminution of detrital material from the cliff-slope, and the scouring action of material transported by longshore currents. Johnson described the lowering of the bench and the development simultaneously of a shore-face terrace, which prolongs the slope of the bench, and, in the later stages, the development of the veneer and continental terrace, giving rise to a long, gradually shelving, submarine slope. He concludes that, under the influence of the powerful waves, the bench will be developed approximating to the horizon of high-water mark, and this bench will slope concavely seaward.

The writer's observations do not support these conclusions wholly. In exposed localities, the bench is in many cases developed in the upper tidal zone, but this is simultaneously accompanied by the development of the secondary bench—the result of erosion of the foreshore when the higher-level bench is uncovered and beyond wave-attack. Rarely is there a pronounced slope to be observed. In sheltered waters there is a tendency for the development of benches on a lower horizon, for in an extreme case the wave-attack will be equally effective at the periods of low and high water. There is simply a vertical increase in the notch, since there is no outstanding difference between the power of the waves at the times of low and high tides.

With regard to wave-action at a depth, conclusions are somewhat conflicting. In the case of oscillatory waves, this is a function of the wave-size. It is generally accepted that off the Atlantic coast of North America a depth of 600 feet represents the lower limit at which fine sand is distributed. To a depth of 100 feet, sand, gravel, and pebbles may be moved. Johnson pointed out that even the larger oscillatory waves at a depth of 600 feet may cause the movement of sand.

The Royal Commissioners on Coast Erosion (Britain), in their final report presented in 1911, stated: "The Commissioners are of opinion that the movement of shingle below low-water line during heavy gales takes place up to a depth of eight fathoms" (quoted by Latham). It is probable that within the area enclosed by the Barrier Reef the movements do not occur to these depths, though under the influence of cyclonic disturbances they may be possible.

It is apparent that translatory and the larger oscillatory waves and currents are important agents of marine erosion, whose activities extend to considerable depths.

As a bench is developed, the disrupted material is swept away, some seaward. Only the larger fragments accumulate to form the shore-face terrace, and this is merely a temporary accumulation. As the notch is enlarged, the bench is lowered by attrition and there comes a time when the platform is no longer a bulwark protecting the cliff. Further benching results. Meanwhile, the earlier bench is being constantly lowered. There can be no accumulation of the finer material in this area; this is deposited at a depth below the zone in which wave and current action are sufficiently strong to move it. One bench is but a single step in the development of the concave marginal profile, which is made up of a series of benches developed successively, and lowered at progressively diminishing rates from the upper zone. The concavity of the profile constantly diminishes as erosion proceeds, and, given stable conditions for a sufficiently long period, the wave-attack would result in the production of a peneplain of marine erosion at a depth determined by the zone of marine erosion. The development of terraces is largely controlled by location and, it may be presumed, are inconstant features determined by the depth of wave activity in the particular locality.

BENCHING AS EVIDENCE OF EMERGENCE IN EASTERN AUSTRALIA.

In any locality, the horizon upon which a bench may be developed is determined by—(1) The nature of the rock and its structural features, (2) location, (3) tidal range—all variable controls. It has been demonstrated that benches of the present marine cycle are developed on various horizons between high and low tide levels. Along the Eastern Australian littoral the benches are juvenile, the secondary benches are small. Following a slight emergence, the latter features would be rapidly effaced.

Following a uniform emergence of the shore-line or lowering of the sea-level, the relative positions of benches remain unaltered and these will then occur on various horizons above high-water level (assuming the movement to have been sufficiently great). It is impossible, therefore, to gauge accurately the magnitude of emergence from the evidence of isolated elevated benches; perhaps not important when the emergence has been great, but becoming extremely so when the movement has been confined to one of the order of ten to twenty feet. This aspect is relevant also to the question of differential elevation. The occurrence of benches on various horizons above high-water level, particularly when such are not separated by a distance greater than the tidal range, is not presumptive evidence of differential movement. In special cases, when the separating distance is slightly greater than the tidal range, a differential movement may not necessarily be implied. On the other hand, the absence of elevated benches may not constitute evidence that there has been no elevation or the equivalent lowering of sea-level.

An analysis of the evidence of movement to which the strand-line is consequent, in Eastern Australia, suggests that this has been uniform rather than differential, and possibly was the result of a negative movement of the ocean, due to a readjustment of the level adjacent to the continental mass after subsidence in the Pacific floor, in a manner suggested by Suess. Superimposed on the Post-Pliocene movement of elevation described by Dr. A. Lawson, there seems to have been a movement of recent emergence of about ten feet of the Californian shore-line.

It is possible that such a movement of the ocean level may have occurred concomitantly with a flexing of portions of Eastern Australia, both arising from a single control. Mr. E. C. Andrews[11] referred to the cycle of depression interrupted by an epicycle of elevation, due to the shifting of the pivotal axis. He mentioned that, while elevations are found on the coast of 15 to 20 feet, traces of contemporaneous elevation exist inland from Townsville of the order of 300 feet. Terraces at Raymond Terrace occur up to 20 feet, while further inland a movement of 50 feet is indicated.

The movement of elevation of 300 feet was suggested by Jack, who described alluvial beds attaining an elevation of 300 feet at the base of the coast range, west of Townsville. These beds have not been shown to be marine in origin.

At Gordonvale (near Cairns), recent beds occur about 100 feet above sea-level, fringing Walsh's Pyramid in the Mulgrave Valley. These are lacustrine in origin and have not been elevated. It is possible that the beds to the west of Townsville may have originated under similar conditions and may not have been subsequently elevated. At Shea's Creek,[12] N.S.W., there has been a slight movement of depression. This has been discussed by Mr. C. Hedley.[3]

The differential movements known appear to have been local in character.

[Since the foregoing article went to Press the writer had an opportunity of consulting a Memoir by Professor R. A. Daly on "The Geology of American Samoa" (Carnegie Institution of Washington, Publication No. 340, 1924). The following conclusion, quoted, has an important bearing on the problem under discussion.

Professor Daly describes the occurrence in Samoa of benches emerged to the extent of 4 to 5 metres, and states:—"Correlation of the facts observed in Samoa, with those observed in the Atlantic and with others described in many parts of the world, has prompted the hypothesis of a world-wide sinking of the ocean level—a eustatic shift. The date of the shift has been assigned, roughly, to an epoch centering around 4,000 years ago."]

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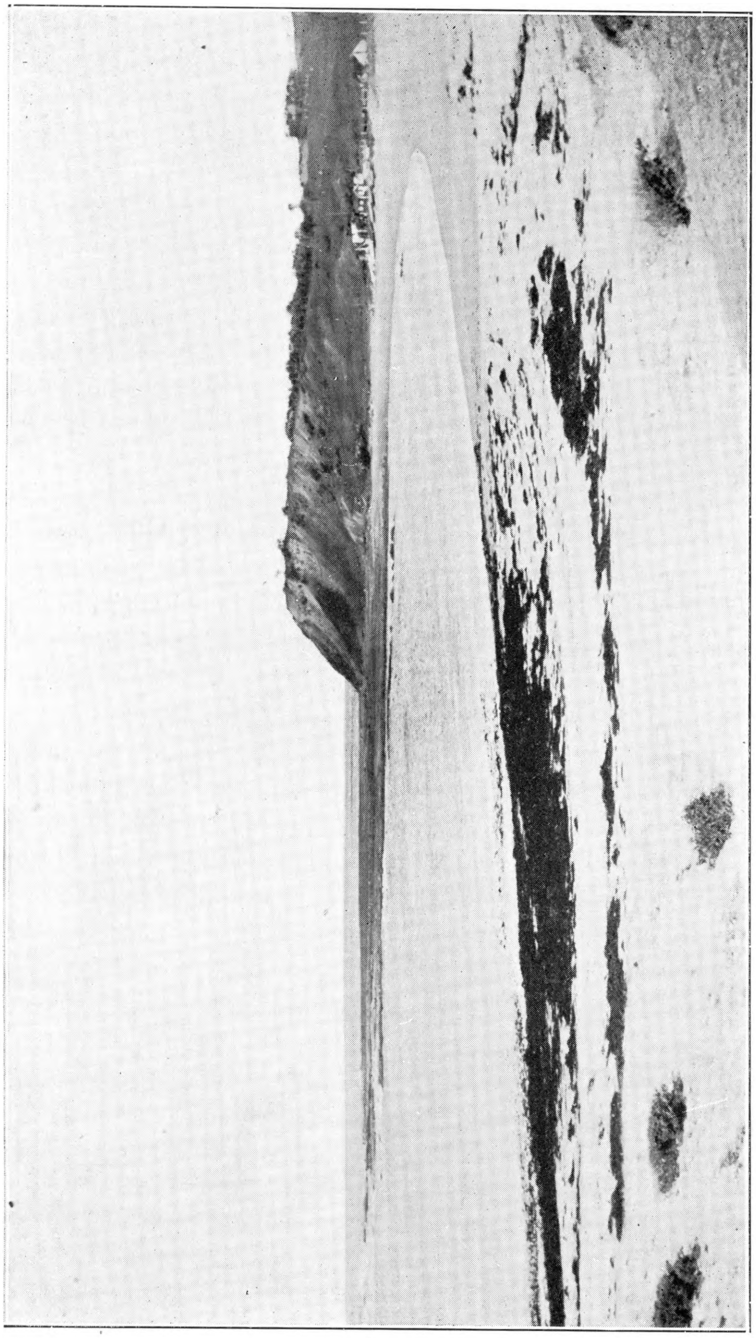
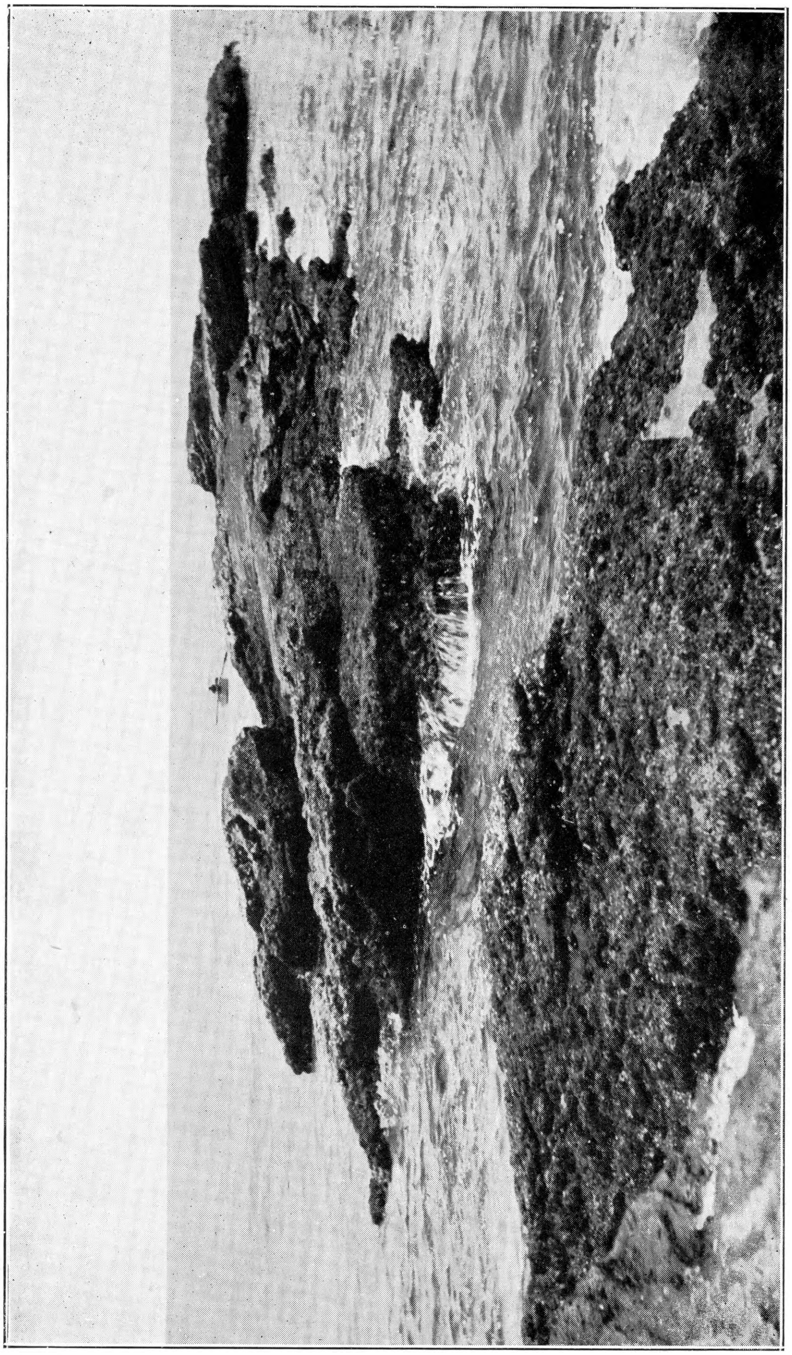


LONG REEF, N.S. WALES.
Bench approximating to the upper tidal limit.

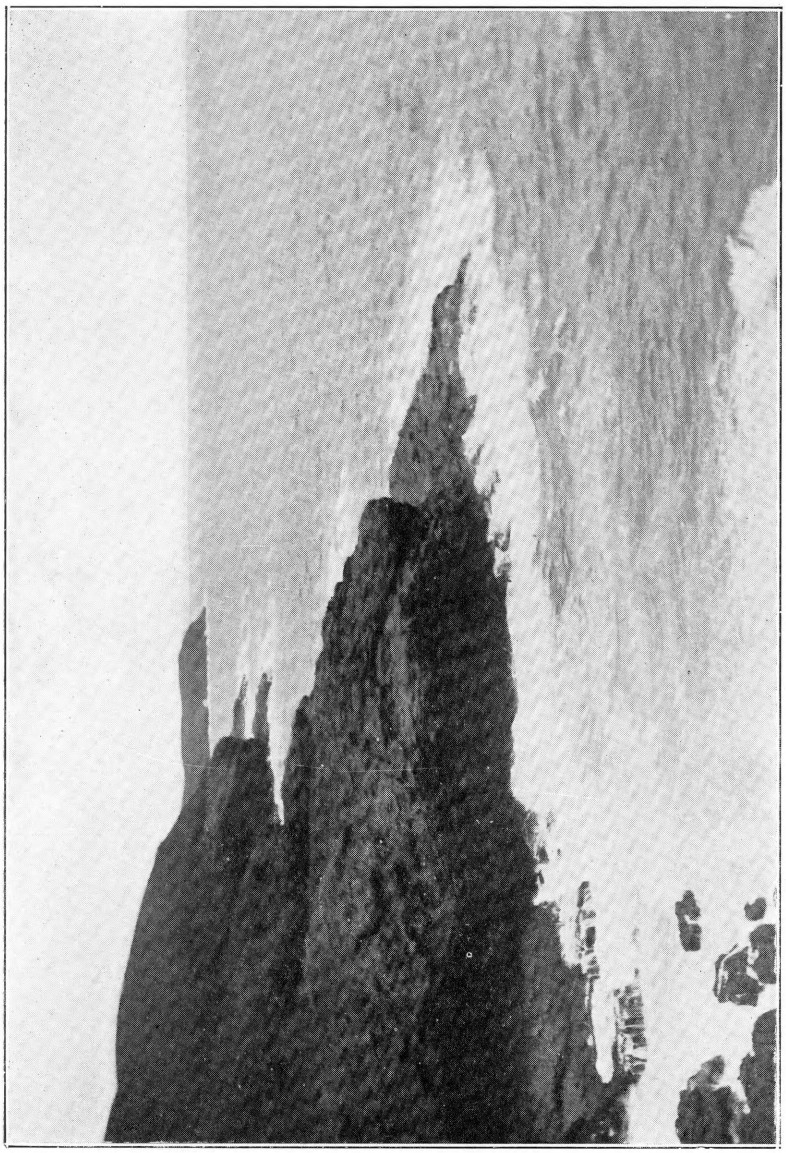
[*Face page* 130.]



BLACK ROCKS, TORRES STRAIT.

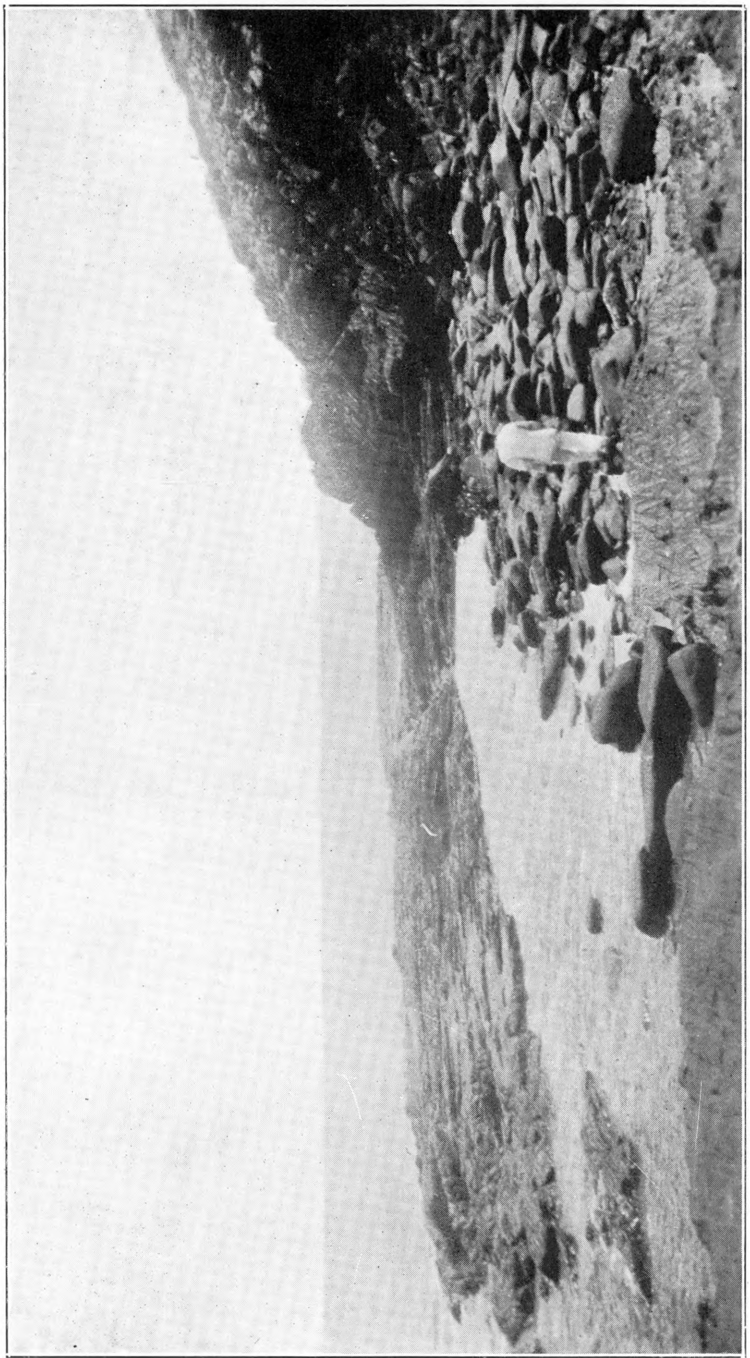
Secondary benches, approximating to lower tidal limit. That in foreground is covered with marine growth.

[*Face page* 130.]



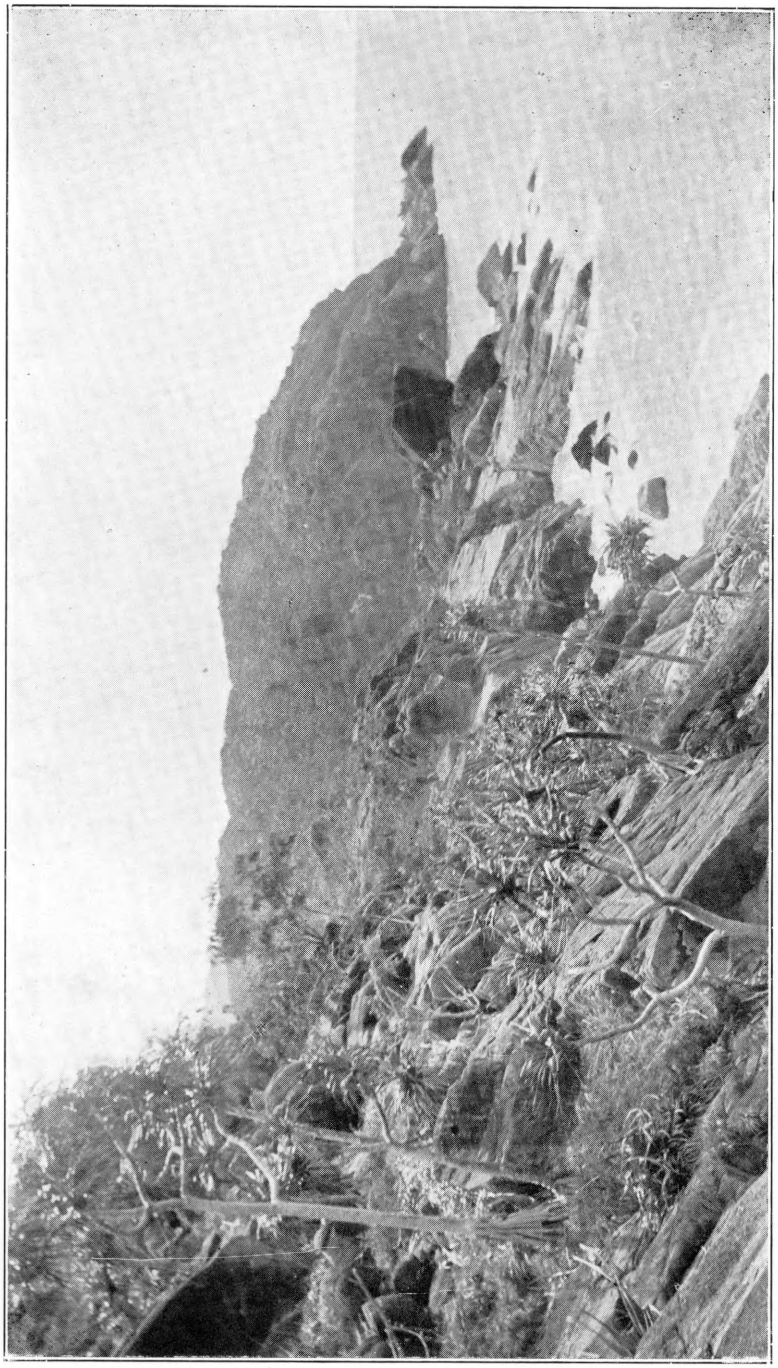
NORTH KEPPEL ISLAND. BENCH.

[*Face page* 130.]



EBORAC ISLAND, NEAR CAPE YORK. BENCH.

[*Face page* 130.]



CAPE GRAFTON.

Joints in Granite dip steeply. Notches are absent. In the distance rubble has accumulated at the foot of the cliffs.

[*Face page* 130.]

THE DRAINAGE OF THE ATHERTON TABLELAND.

F. JARDINE, B.Sc., Science Research Scholar, Deas Thomson (Mineralogy) Scholar, John Coutts Scholar, University of Sydney (co-operating with the Great Barrier Reef Committee).

(Plates XXIII., XXIV., XXV., and Three Text Figures.)

No. 14.

INTRODUCTORY.

Geological and topographical features of portions of the Atherton Tableland and marginal coastal strip have been described by many writers. The most comprehensive account of the physiography of the area is that by Dr. Danes.[1] Large areas in this locality remain as yet geologically unexplored. In order to form a basis for the discussion of the drainage of the tableland, it is necessary to outline briefly the main physiographic features. Details of certain features not previously described are added. References to earlier contributions occur in subsequent sections of this paper.

The writer wishes to acknowledge the generous assistance accorded him by the Great Barrier Reef Committee.

GENERAL.

About twenty-five miles north of Cairns the divide between the E.- and W.-flowing river systems approaches the coast-line. Some seventy miles to the south, the divide is distant over fifty miles from the shore-line and is retreating rapidly.

The wedge-shaped area east of the main divide comprises the Barron-Atherton Tableland (1,500 to 2,500 feet) and the Evelyn or Herberton Tableland to the south-west, about 700 feet higher. The latter for some distance presents an abrupt linear scarp trending from S.E. to N.W., which, north of Atherton, slowly subsides. South of Mareeba the scarp is not a prominent feature though it divides the Barron waters from those of Walsh River.

The true scarp of the Barron-Atherton Tableland forms an arc of low curvature which approaches the coast north of Cairns, from where it swings gradually southward, presenting an unbroken wall rising in places to over 2,500 feet, as far as the Barron canyon. South of this canyon the character of the scarp is profoundly

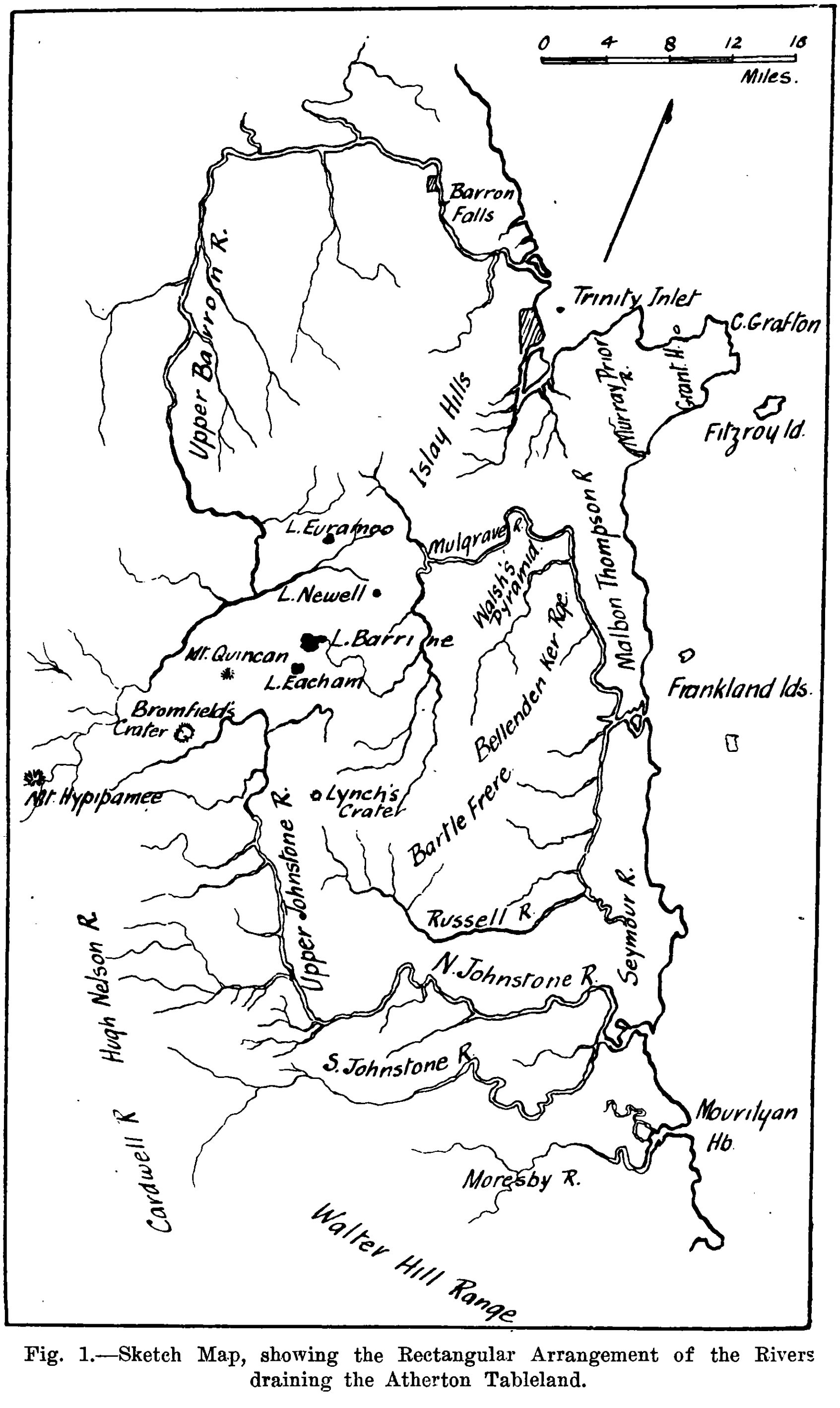


Fig. 1.—Sketch Map, showing the Rectangular Arrangement of the Rivers draining the Atherton Tableland.

modified. It is gashed by gorges cut by the Mulgrave, Tringilburra, Russell, and Johnstone Rivers, and these isolate the Islay Hills, Walsh's Pyramid—Mount Harold, Bellenden-Ker (5,187 feet), Bartle Frere (5,281 feet) Ranges. While the latter ranges are the highest in Queensland, the main divide is some thirty miles to the west.

Northward, the tableland scarp overlooks a narrow strip of coastal plain which broadens southward towards Cairns where the Barron is advancing its mouth into Trinity Bay by way of a cuspate delta. South of Cairns the alluvial strip continues to fringe the foot of the scarp, but it becomes enclosed by the Coast Ranges which rise 2,000 to 3,000 feet. These alluvial deposits form the floor of a corridor about four miles broad, which finally opens to the sea fifty miles to the south, at Double Point. The Cape Grafton Peninsula is composed of two short parallel ranges—Grant Hill (1,300 feet) and Cape Grafton Range (1,230 feet)—tied-on to the Nisbet Range (1,765 feet) by intervening narrow alluvial strips.

THE RIVER SYSTEMS.

The streams draining the Atherton Tableland are disposed in a characteristically rectangular manner.

The divide between the Johnstone and Barron Rivers occurs ten to twelve miles south of Atherton. The Barron flows northward for thirty miles, the Johnstone southward for twenty miles, when each flows eastward to the sea. Almost symmetrically arranged and completely enclosed by the Barron-Johnstone rectangle is the Russell-Mulgrave River system, and this forms an almost complete rectangular network of streams (see Fig. 1). The headwaters of the Upper Mulgrave and the headwaters of the Russell are distant but eight miles from the main Barron and Johnstone channels respectively. The present drainage is an obviously unstable one, and clearly demonstrates the juvenility of the physiography.

THE BARRON-JOHNSTONE DIVIDE.

(See Fig. 1 and Plate XXIII.)

The divide between the Barron and Johnstone Rivers is linear and trends from S.W. to N.E. across the Atherton Tableland. At the present time it is an almost imperceptible feature. The topography is more or less mature, consisting of undulating basalt swells with here and there more or less isolated hills rising in one case to 600 feet above the general level of the tableland. The divide is characterised by the presence of a series of extinct volcanoes, the craters of several of which are occupied by lakes; these volcanoes are arranged in a linear manner, and it is the extruded materials from these which constitute the divide. The divide was originally six to eight miles broad, but by subsequent erosion has been reduced to a mere line traced on the map. With the exception of Lake Eacham and possibly Lake Newell (mapped on the divide, Lamb Range, between the Barron and Mulgrave Rivers, but not generally known to residents of the Atherton Tableland), none of the volcanoes observed by the writer occur on the present line of parting.

LAKE EURAMOO.

This lake occupies a caldera six to seven miles north of Lake Barrine, on the divide between Robson and Severin Creeks, which rise in Lamb Range and flow to the Barron. The elevation of the lake by aneroid measurement is 2,380 feet. The enclosing crater walls on the south are 80 to 90 feet higher; the northern walls appear to be much lower. The crater slopes are covered by a dense tropical scrub, and a thickness of subsoil obscures the rock outcrop. The inner slope of the crater wall is gentle, being 20° to 25°. The lake occupies only a portion of the floor of the crater and is fringed by dense swamp vegetation. South of this lake basalts occur, and through these the Barron River has notched, exposing the underlying granite.

LAKE BARRINE.

(See Plates XXIII.–XXIV.)

Lake Barrine lies about three miles north of Lake Eacham and is by far the largest of the caldera lakes. In official publications the length given is 60 chains, breadth 30 chains, and area 256 acres. The lake lies within the fork formed by Congo and Maroobi Creeks, both Barron waters; but the lake has an overflow drainage to Toohey Creek, which flows to the Mulgrave. The level of the lake by aneroid measurement is 2,400 feet, some 70 feet below the Lake Eacham level. The enclosing walls are 90 feet above the surface of the lake. In a recent road-cutting on the outer slopes, the geological structure of the cone is clearly shown;

it is composed of alternating beds of coarse and fine grained tuff or ash with regular "bedding planes." (See Plate XXIV.) Occasionally beds of agglomerate are encountered. Distributed through the ash-beds, which dip gently outwards from the crater at 15°, included fragments up to two feet in diameter, of mica schists and amphibolites, are frequently seen. These are disseminated generally. The crater walls are of fairly uniform elevation, but appear to be slightly lower on the south. The inner slope to the crater is gentle and the lake is apparently much shallower than Lake Eacham. Infilling by the erosion of the walls is an effective factor in silting. The outer slopes are being dissected by streams which reach the Barron, particularly on the western and southern slopes. The lake-level fluctuates but slightly, since there is an overflow drainage to the Mulgrave.

LAKE EACHAM.

(See Plates XXIII., XXV.)

Lake Eacham, the best known of the crater lakes of the Atherton Tableland, is 46 chains long and 38 chains broad; its area is 130 acres. The lake is on the line of parting of the Johnstone and Barron Rivers. The lake surface, by aneroid measurement, is 2,473 feet above sea-level and the crater walls are 100 feet higher. These are composed largely of tuff or ash beds, extremely soft and crumbly, which dip from the lake outwards at 15°. On the S.E. slopes of the cone mica schists intruded by quartz veins occur, and the latter may be seen again at the water's edge. The tuffs vary in texture from coarse to fine grained. The beds often contain large blocks of granite and gneiss. The continuity of the S.E. wall is broken by a small indentation which Dr. Danes regarded as being a second crater. On the northern shore of this indentation fragments of lava, very much decomposed, with included fragments of granite, were observed. The inner slope of the crater walls is steep, in places almost vertical. The outer slopes are more gentle. The ash-beds dip outwards from the crater at 15°. The depth of the lake, measured by Mr. A. Goulet, is 226 feet. The lake contains innumerable small fish. It is said that the aborigines had a superstitious dread of the lake (mentioned by A. Meston). On the low eastern walls traces of visits by the aborigines are apparent. The writer found an aboriginal tomahawk of quartzite and numerous waterworn pebbles which were evidently used as hammer stones.

MOUNT QUINCAN.

(See Plate XXIII.)

At a distance of rather less than two miles south of Yungaburra, at Chumbrumba, Mount Quincan rises to 2,930 feet (aneroid measurement). This hill is a fine crateriform volcanic cone whose summit is approximately 600 feet above the surrounding flats. The western walls of the crater are highest, being 200 feet above the general wall elevation. The crater is circular in outline and about 100 feet deep (300 feet below the hill summit). The inner slope to the crater is steep, the angle of slope being 45°, while the outer slope of the cone is about 30°. The floor of the crater is dry; water accumulates for a short time after a heavy downpour. The rocks composing the cone are obscured by a great thickness of loose, porous, chocolate and yellow soil, scattered through which abundant pumiceous fragments, blocks up to eighteen inches in diameter of grey scoriaceous olivine basalt, as well as fragments of altered granite occur. The cone is more or less symmetrical about an E.-W. axis. From the high western wall the hill slopes gently towards the west, expanding in a broad fan. Leslie Creek is intrenched to the extent of eight feet in red soil. Close by large blocks of basalt occur scattered over the surface. The cone is dissected only to a minor degree and the crater is intact. The hill formerly was covered by a valuable red cedar forest.

Towards Pinnacle Pocket several craterless domes occur.

BROMFIELD'S CRATER.

This is a large lava crater cone lying about twelve miles S.S.W. of Lake Eacham. The crater forms an oval depression about 150 feet below the crater walls, which are not appreciably higher than the general tableland level of the locality (2,590 feet approx.). The rocks of the walls are obscured, but occasionally boulders of compact basalt were observed on the inner slope to the crater; the angle of slope is about 15°. The floor of the crater is swampy and the eastern portion is occupied by lagoons. The cone has been breached by a tributary of Nicholas Creek which flows to the Barron.

LYNCH'S CRATER.

This, also a lava crater cone, lies about six miles due east of Malanda; it occurs on the divide between the Johnstone, Mulgrave, and Russell Rivers. This cone repeats the features of the Bromfield lava-cone. The crater is also 150 feet deep, but much smaller, being about ½-mile long and ¼-mile broad. The crater floor is plane and marshy. The inner wall slope is at an angle of 25°. There is no apparent outer slope, the crater being of the nature of an oval pit in a broad basalt swell which has been somewhat dissected. On the inner slope, boulders of grey vesicular and compact basalt were obtained which were found to be olivine basalts similar in all respects to the olivine basalts of the Barron-Johnstone divide. The crater wall has been partly notched by a stream which flows to the Johnstone River.

MOUNT HYPIPAMEE.

Mount Hypipamee occurs in the dissected region of the Evelyn Plateau scarp about twenty miles south of Atherton. The curious features of this mountain have been described by Mr. R. C. Ringrose.[2] It typifies the explosive character of the final phase of vulcanism in North Queensland.

* * * * * *

The volcanic cones occurring on the Barron-Johnstone divide clearly demonstrate from their characters extreme phases of volcanic activity. The calderas of Eacham and Barrine apparently were associated with volcanic action of an explosive character with little or no extrusion of lavas. From such foci as Lynch's and Bromfield's craters the olivine basalts of the divide appear to have quietly welled forth over a restricted area of the tableland. Mount Quincan, probably, was both explosive and quiet in character.

A remarkable feature of the volcanoes is the undissected character of the cones and the almost perfect state of preservation of the craters. Undoubtedly these, together with the extrusions in the Upper Mulgrave and Russell Rivers, Greenhill in the Mulgrave corridor, represent the final paroxysms of vulcanism in the area. The plateau basalts to the south are undoubtedly older, but from the physiographic evidence the writer concludes that those enumerated are Post-Pleistocene in age.

THE LOWER MULGRAVE, RUSSELL, AND JOHNSTONE RIVERS.

The extent of the delta lands about Trinity Inlet, charted by King, led most naturally to predictions by early investigators that these marked the entrance to the sea of a large freshwater stream.

In 1848 Captain Stanley, accompanied by Macgillivray, attempted an investigation of this inlet, in the pinnace of the "Rattlesnake," but abandoned the project after encountering shoals. It remained for Dalrymple,[3] leader of the Queensland North-east Coast Expedition of 1873, finally to demonstrate that no large stream entered Trinity Bay by way of these delta lands. Dalrymple wrote: "In the centre of the southern arc of the bay a broad opening of an apparently large river appeared . . . a low bald grassy hill, green as emerald, rose from the low land towards Walsh's Pyramid. . . . In every direction the channel of this estuary broke up and ended abruptly in mangrove swamps." Dalrymple was unable to penetrate these swamps, but later explored the Lower Mulgrave-Russell valley, having penetrated in his boats for a considerable distance upstream from the river mouth. He wrote: "This fine valley, which I named the 'Vale of Mulgrave,' averages four miles in breadth from range to range. . . . With the exception of a limited extent of mangrove flats in the lowest level of drainage opposite the junction, and between it and the base of Bellenden-Ker, the valley is full of dense jungles, similar to those upon the Johnstone, and appears to be a northern extension of that fine alluvial district."

The Mulgrave River issues from a deep gorge between the Islay Hills on the north and Walsh's Pyramid on the south, flowing towards the N.N.E. At Gordonvale, the stream turns E., then S.E. down the "Vale of Mulgrave," unites with the Russell, and finally reaches the sea through a gap between the Malbon Thompson and Graham Ranges (Coastal Ranges).

From Cairns, as far south as Babinda, the highest point in the valley floor occurs at Meringa (seventy-two feet), two miles north of Gordonvale, and this eminence coincides with the divide between the Mulgrave and the streams of Trinity Inlet. It is on this divide that Green or Emerald Hill occurs.

The youthfulness of the divide north of Gordonvale was apparent to Jack,[4] who concluded that "the Mulgrave River has evidently at one time entered the sea at Trinity Bay, but has been deflected—probably by the flows of basalt which fill up its valley down to the point where it turns sharply round to the south to flow into the sea at Port Constantine."

In spite of its prominence and accessibility, Emerald Hill, now generally known as Green Hill, remained unexamined until it was demonstrated by Dr. Danes that this hill was a surviving portion of a small volcanic cone. This writer also concluded that the Mulgrave at one time emptied its waters into Trinity Bay, for he stated[1]:—"La vallée est comblée par des alluvions argilo-sableuses, sous lesquelles on trouverait, ca et là, des racines de Palétuviers fossiles; la plus grande partie provient des apports et des dépôts de la Mulgrave R. Bien que je n'en aie aucune preuve directe, je suis amené à penser que la Mulgrave R. se terminait jadis par le delta du Trinity Inlet, plus que, vraisemblablement à la suite de l'éruption du Green Hill, elle s'est détournée dans sa direction actuelle et a apporté ses caux à la Russell R."

The writer is able to confirm to a great extent Dr. Danes's observations. Green Hill is about 300 feet high and is composed of chocolate and red soil with numerous boulders of grey and chocolate scoriaceous and vesicular basalt. The eastern walls of the crater are absent. A stream drains from crater to Trinity Inlet. The angles of slope of the crater walls are 35° to 45° externally and 25° internally. The hill is situated on a flat "pancake" base of basalt thirty to forty feet above the general level of the valley floor. The basalts have welled out athwart the valley floor, and westward the decomposed flows are traceable in the rich fields of chocolate-red soil under sugar-cane cultivation. The writer is unable to agree with Dr. Danes that there has been no extrusion of lavas. The lava-flows constitute the divide between the Trinity Inlet waters and those of the Mulgrave River, and this divide is scarcely 100 feet high. There is no doubt that the Mulgrave at one time entered Trinity Bay in the manner suggested by Jack and Danes. Evidence is available which demonstrates that this stream was dammed and lacustrine conditions imposed for a considerable period.

THE TERRACES OF THE MULGRAVE VALLEY.

(See Fig. 2 and Plate XXV.)

As the Mulgrave issues from its gorge to the "Vale of Mulgrave," it is intrenched to the extent of seventy-five feet in the silts of the valley, and the river course is characterised by the development of terraces; these are illustrated in Fig. 2. Fringing Walsh's Pyramid, a high-level terrace (seventy-five feet above the river by aneroid measurement) extends, broadening southward as the river swings towards the eastern valley wall; this terrace

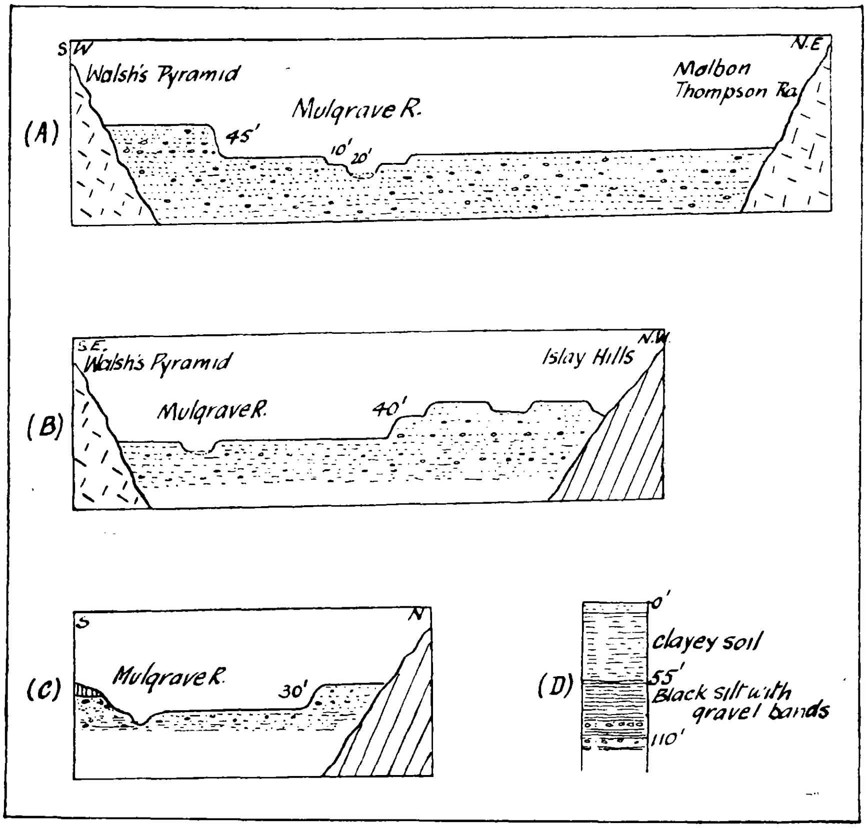


Fig. 2.—The Mulgrave River Terraces: (*a*) About ½ mile south of Gordonvale; (*b*) About 2½ miles west of Gordonvale; (*c*) Near the junction of the Mulgrave and Little Mulgrave; (*d*) Section supplied by Mr. J. J. O'Leary.

overlooks, at Walsh's Pyramid, a second terrace ¾-mile broad which is thirty feet above the river-level, and this narrows southward towards Aloomba. The 30-foot terrace overlooks a smaller terrace twenty-five paces broad, but twenty feet above the river-level. On the left bank of the stream, here, the 75-foot terrace is absent.

The high-level terrace is subjected to flood erosion (Fig. 2 (A)). Upstream two or three miles from Gordonvale, the high-level terraces are repeated on the left bank of the stream. Here they are smaller and somewhat dissected (Fig. 2 (B)). As far upstream as the junction with the Little Mulgrave, the Mulgrave is fringed in a fragmentary manner by terraces, which, as the river-gorge assumes a juvenile character, become fragmentary and limited in extent. They are found hanging on the valley sides forty feet above the river-bed (Fig. 2 (C)).

At Gordonvale the Mulgrave is but twenty-five feet above sea-level. Southward, this river and also the Russell are fringed continuously by terraces composed of rich loam which constitute the fertile sugar-cane lands.

Mr. J. J. O'Leary, shire engineer at Cairns, has kindly supplied information regarding the silts in the Mulgrave Valley (Fig. 2 (D)). He has bored to a depth of 110 feet at Gordonvale, passing through a few feet of surface soil, 50 feet of clayey soil, to 110 feet through black silt with bands of gravel and wash. At Deeral, about twelve miles to the south, Mr. O'Leary bored thirty feet below the river-bed, passing through stiff soil.

Thus both banks of the Mulgrave are characterised by the development of terraces in alluvium which rise seventy-five feet above the stream. The deposits forming the floor of the valley are to be regarded as being lacustrine in origin, deposited in a basin formed by the damming of the stream by the extrusion of basalt from the Green Hill volcano. In this basin the materials transported by the steeply falling streams from the enclosing heights were deposited.

The divide between the Russell and Johnstone Rivers in the Mulgrave corridor repeats to a certain degree the features of the Mulgrave-Trinity Inlet stream divide. This divide also is composed largely of basalt and rises to 100 feet. The divide is occupied by the extensive Eubenangee swamps, which are drained by streams flowing to both the Russell and Johnstone. The Lower Johnstone flows through rich flats of alluvium through which rise hills composed of slates and schists, upon one of which Innisfail is situated. The North Johnstone is fringed by terraces similar in character to those fringing the Mulgrave, and rise to sixty feet (approx.) above the river-bed.

But for the presence of these two divides, which are minor features, and hills further south, the corridor floor is plane and opens to the sea south of Double Point, with North and South Barnard Islands, probably, drowned relics of the east and west corridor walls.

(The terraces referred to by Jack as the "Russell Terraces" are alluvial workings capped by basalt at an elevation of 2,000 feet in the Russell River headwater region.)

THE EVOLUTION OF THE DRAINAGE.

Jack[5] stated his conclusions regarding the evolution of the Mulgrave, Russell, and Johnstone as follows:—

"It seems probable that the valleys of the Mulgrave, Russell, and Johnstone were dammed up by a volcanic outbreak early in Miocene times, so as to form a vast lake, in which for a time a fine siliceous sand was quietly deposited; that the barrier was at length broken down by the stream at the outlet of the lake, and numerous torrents removed the greater part of the sand and brought down gravel charged with gold; and that a second barrier was thrown up and a great thickness of fine silt again deposited, and that over the nearly level surface thus produced immense flows of basalt were finally poured out, filling up the lake. The waters draining this area, if the lake had not been filled up, would have found their way to the sea by a single outlet, instead of forming as they do three independent rivers. The immense amount of denudation since Miocene (?) times is evident when we consider the number and depth of the valleys, which have been carved in places more than 1,000 feet deep, through basalts, old river- and lake-beds, and slate and granite rocks."

Dr. Danes's[1] conclusions were somewhat different:—"Il n'y a pas de doute que la Barron R. supérieuse ait été jadis la tête d'un fleuve coulant vers le Nord. La ligne de partage des eaux était alors plus à l'Est, vraisemblablement le long de la chaîne côtière actuelle. Le continent s'est étendu jusque fort avant dans la mer de Corail, et de grands bassins d'eau douce ont occupé les aires de drainage de la Barron R. et de la Russell R., bien au-dessus du niveau d'érosion actuel. A la fin du Tertiaire se produisirent les grands effondrements; une vaste bordure du continent disparut, par morceaux successifs, sous le niveau de la mer; dans la région côtière actuelle se dissinèrent des zones d'effondrement linéaires, en forme de 'Graben,' tandis que les croupes et les massifs granitiques se relevaient en bloc. Seule la pénéplaine ancienne resta immobile et fut simplement recouverte par de vastes nappes de basalte. La chaîne côtière et les montagnes de la péninsule du cap Grafton subsistèrent longtemps à l'état d'îles séparées par des détroits marins. L'action puissante du comblement des fleuves et des torrents, unie à un léger exhaussement du sol, les a rattachées à l'arrière-pays.''

It is clear that it was from the evidence of the drifts underlying the plateau basalts at the head of the Russell River (the so-called terraces) that Jack postulated deposition in a lake basin which was subsequently infilled by lava-flows. It is to be inferred also that Jack regarded the Mulgrave-Russell corridor as being excavated by stream erosion, and this does not appear to be justified. Danes on the other hand, while he recognised in the Mulgrave-Russell corridor a tectonic feature, postulated the occurrence of large freshwater basins into which the Barron and Russell and presumably the Johnstone also drained, before the movements of late Tertiary or early Pleistocene time. The writer can see no justification for this assumption. The evolution of the drainage of the Atherton Tableland is characterised by simplicity, and the processes of the stream evolutions may be followed readily from a consideration of the physiographic features.

While stratigraphical evidence of tectonic movements in this area is not available (this is masked by extensive basalt-flows or alluvial deposits of great thickness), satisfactory evidence is afforded by the physiographic features. The occurrence of large blocks which have undergone differential movements, and which are bounded by more or less meridional fault planes, is evidenced by the Evelyn Tableland scarp, the Atherton Tableland scarp, the Mulgrave-Russell corridor, which clearly is a small rift valley, as well as the two smaller rifts of the Grafton Peninsula; the more or less mature character of the tableland surfaces and the limited dissection of the bounding scarps demonstrate, too, the youthfulness of these features, which are considered to pertain to the Kosciusko epoch.

The Barron, Mulgrave, Russell, and Johnstone Rivers in their present form post-date the foundering of the eastern marginal extension of the continent; there is no evidence which indicates that these streams drained into freshwater lakes in pre-Kosciusko times, as suggested by Dr. Danes.

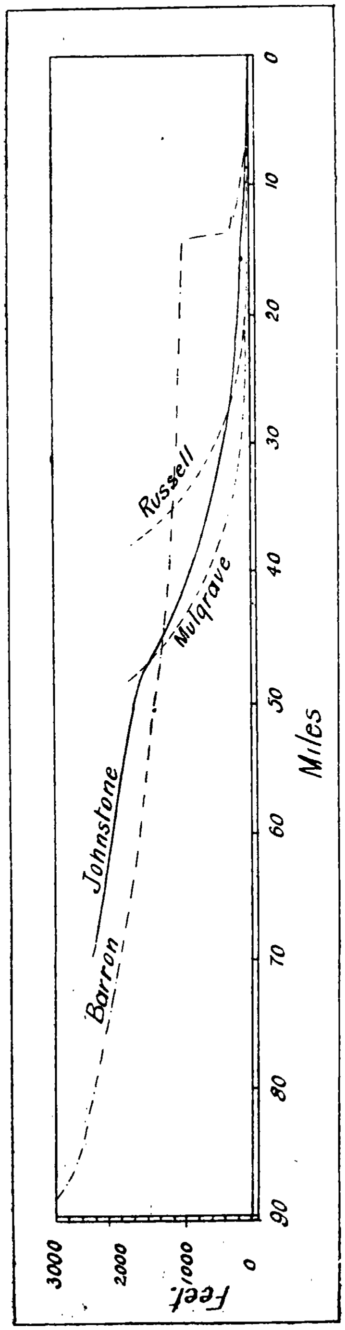


Fig. 3.—The Atherton Tableland Stream Profiles.

In Fig. 3 the tableland stream profiles are shown. It will be apparent that all are juvenile, and also that there has been a remarkable uniformity of dissection of the plateau by individual streams. (The Lower Mulgrave and Russell River courses for twenty miles or so are along the Mulgrave-Russell corridor east of the plateau scarp.) All fall steeply in profound gorges, having merely notched the edge of the tableland. Headward erosion by the Barron has been limited by resistant quartzites, &c., dipping almost vertically, which the stream traverses nearly at right angles to the strike. This stream plunges over a precipice about 700 feet high, finally emerging from a deep canyon. The differences in characters between the descents of the Barron and the remaining streams are due solely to the character of the rocks traversed. It is clear that the scarp of the Barron-Atherton Tableland was formely the main divide, and that this divide was breached by the short, steeply falling streams. The Upper Barron and Upper Johnstone differ from the Upper Russell and Mulgrave in that the headwaters of the former two drain north and south of the tableland, and there the valley sections closely approach the mature form.

It was first suggested jointly by Messrs. Hedley and Taylor,[6] and later confirmed by the investigations of Mr. Poole[7] and Dr. Danes, that the present Upper Barron was formerly the Upper Mitchell River and had been captured by the short E.-W.-flowing Barron.

The headwaters of the Barron and Johnstone flow parallel to and in close juxtaposition with their divide, distant from one another about eight miles. Each of the rivers, in its headwater area, is shaped roughly in form of the letter T, and it is a significant fact that the Upper Barron and Upper Johnstone are in alignment. The slope of the tableland is from south to north; the divide between these streams is low, and is comparatively recent in age. The writer concludes that the Upper Johnstone and Upper Barron formerly formed the Upper Mitchell, and this stream was subsequently broken by the extrusion of the lava barrier of the present divide. It is probable that the Johnstone, which has effected more powerful erosion of the plateau than the Barron, was slowly encroaching on and capturing the very headwaters of the Mitchell, while the Barron, which was much more favourably situated, did not effect capture for some considerable time. The features of the present Barron-Mitchell divide indicate that this capture did not occur until fairly recent time.

Before finally considering the sequence of evolutionary changes it is necessary to discuss the evidence offered in the Mulgrave-Russell corridor. From the low basalt divides of the Johnstone and Russell Rivers, of the Mulgrave and Trinity Inlet streams, the presence of the alluvial terraces rising to seventy-five feet above the present streams, the extensive delta deposits about Trinity Inlet without a large stream, it is possible to reconstruct the old drainage. The Mulgrave-Russell corridor was formerly occupied by a single large stream which entered Trinity Bay by way of the delta lands of Trinity Inlet. Subsequent extrusions of lavas dismembered this stream and in the corridor a series of lake basins were formed, into which the streams of steep gradients from the coast ranges and plateau scarp deposited, to a considerable thickness, the material derived from the granites, shales, schists, and basalts of the marginal highlands. The presence of terraces fringing the Mulgrave as far as the junction with the Little Mulgrave clearly indicates the recent age of the basalt extrusions, for the stream had breached the plateau scarp, and as far as the Little Mulgrave the gorge approached base-level.

Subsequently, by headward erosion, short streams breached the Coastal Ranges and drained the lakes. The stream which breached the Malbon Thompson and Graham Ranges captured the drainage of the northern lake and formed the present Mulgrave-Russell system. That which breached the Seymour Range and drained the southern lake evolved into the present Johnstone system.

CONCLUSION.

The history of the drainage of the Barron-Atherton Tableland may be traced back with accuracy only as far as Pleistocene times. The movements of the Kosciusko epoch culminated in the differential movements of the plateaux and the throwing down of the eastern land extension. To this period the structural features mentioned are considered to belong.

The divide between the east-flowing and west-flowing streams coincided with the scarp of the Barron-Atherton Tableland. To the west of the divide, the Mitchell by gradual expansion drained the tableland, flowing from south to north. East of the divide (Bartle Frere, Bellenden-Ker, etc.), as yet, there is no evidence which indicates whether the Mulgrave-Russell corridor was occupied by a stream or by the sea, but it is clear that, after subsequent drowning, the Coastal Ranges of this area were separated from the mainland by a narrow passage, resembling somewhat the features of the present-day Hinchinbrook Channel and Island. (Borings at Cairns in connection with harbour works show that twelve feet of sand overlie forty feet of dark mud, which passes into a firm clay. Unfortunately, fifty-two feet is the greatest depth to which bores have been sunk. North of Green Hill the vegetation is sparse eucalypt scrub with tea-tree and mangrove swamps. South of the divide the dense luxurious tropical scrub, now largely cleared for sugar-cane farms, occurs. The contrast in vegetation is probably due to the fact that the deposits north of the divide were deposited under marine conditions, while those south of the divide are lacustrine in origin and overlie the marine beds.) The Barron, Mulgrave, Russell, and Johnstone Rivers were at this period short torrential streams gradually notching the abrupt plateau wall, and by degrees the silting up of the passage which isolated the Coast Ranges was effected. Erosion by the southern streams proceeded more rapidly than that by the Barron, for the former were able to direct their attack along the junctions of granite and metamorphic rocks, or along joint planes developed in the granite. The Barron sawed across the uniformly resistant metamorphic rocks.

A slight emergence after infilling (demonstrated by Dr. Danes) resulted in the reclamation of the Mulgrave-Russell corridor floor and the tying-on to the mainland of the Coastal Ranges, Grant Hill and the Cape Grafton Range. The short, steeply falling streams from the tableland now united and flowed from the south to Trinity Inlet. Subsequently the lateral E.-W.-flowing streams breached the divide. The N.-S. courses of the Upper Mulgrave and Little Mulgrave appear to have been determined by erosion along the junctions of granites and metamorphic rocks. The headwaters of the present North Johnstone commenced to capture the headwaters of the Mitchell River. Then followed the extrusion of lavas both on the tableland and in the river valleys, and these dismembered the drainage systems. The Upper Mitchell was probably dammed for a short period and this lake drainage subsequently captured completely by the Johnstone. The Barron later captured that portion of the Mitchell north of the Eacham divide. The lakes in the Mulgrave-Russell corridor became drained by streams which breached the Coastal Ranges, and the present river systems were inaugurated. These have since intrenched their channels in the lacustrine beds of the corridor.

Few islands occur in the offshore area. Fitzroy Island appears to prolong the Cape Grafton Range, and the parallelism of arrangement is preserved if High Island is considered to be a fragment of the Murray-Prior Range. The trends of the Coastal Ranges and tableland scarps are from S.S.E. to N.N.W. The openings through the Great Barrier Reef—Flora Pass, Grafton Passage, and Trinity Opening—trend from S.W. to N.E. It is probable that these passages mark the old stream valleys in the foundered strip; the drainage was from south to north swinging to the east from the old Bellenden-Ker-Bartle Frere Main Divide, which apparently was a line of residuals of considerable altitude of the previous erosion cycle. Trinity Opening probably marks the foundered valley of the N.-E.-flowing pre-Mulgrave stream which was so profoundly modified by the crustal movements of the Kosciusko epoch. While the present Mulgrave occupies a tectonic rather than an erosion valley in its lower course, it is probable that Trinity Opening marks the eroded valley of the precursor of the modern stream in the foundered continental border.

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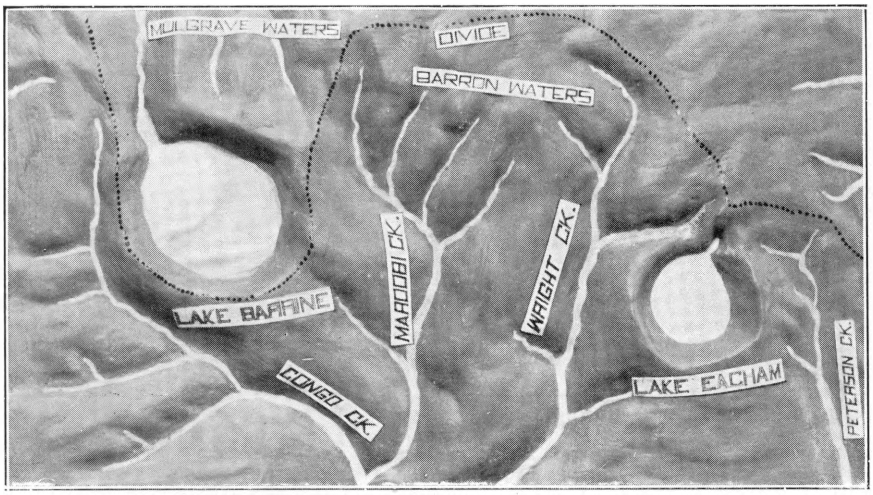
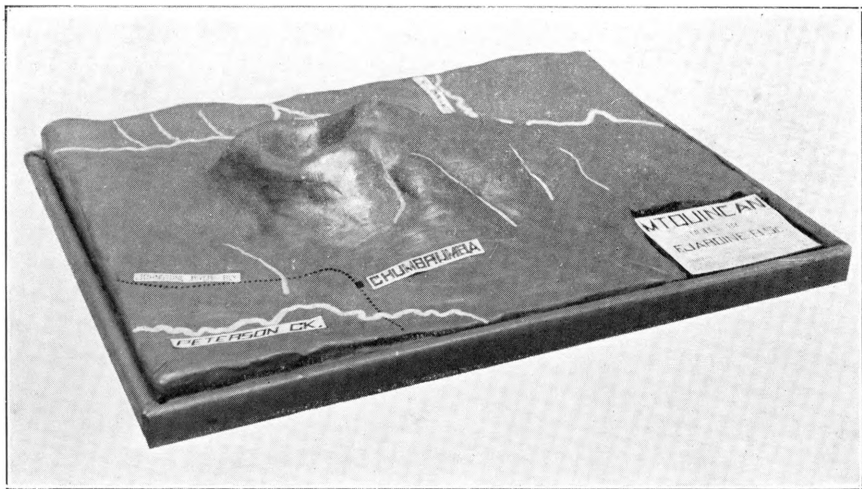
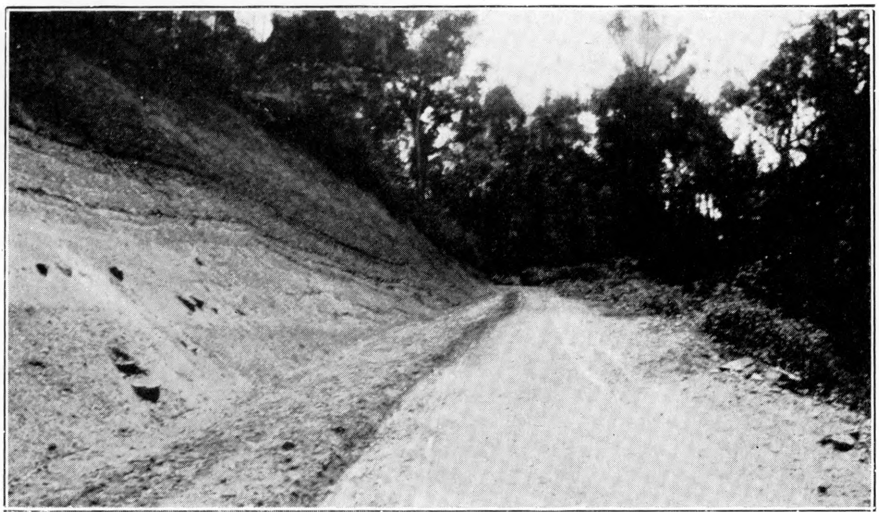


Model to Show Topography of the Barron-Mulgrave-Johnstone Divide.

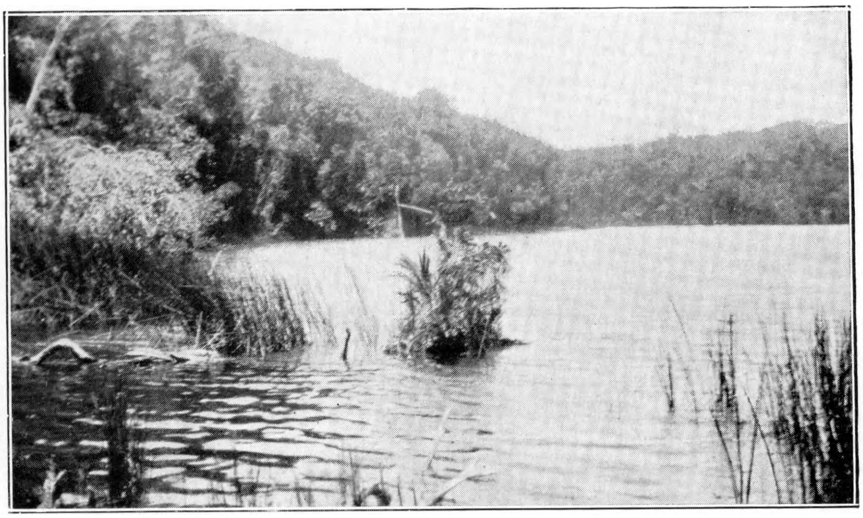


Model of Mount Quincan, on the Atherton Tableland.

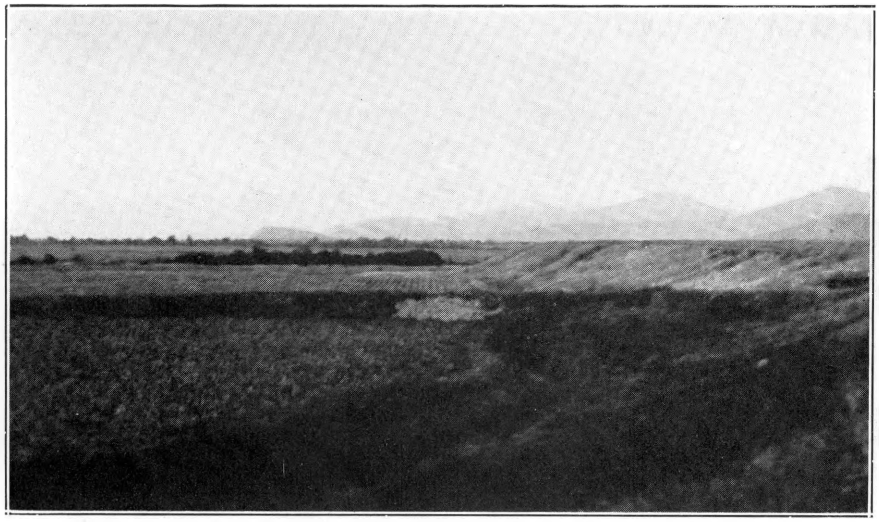
[*Face page* 148.]



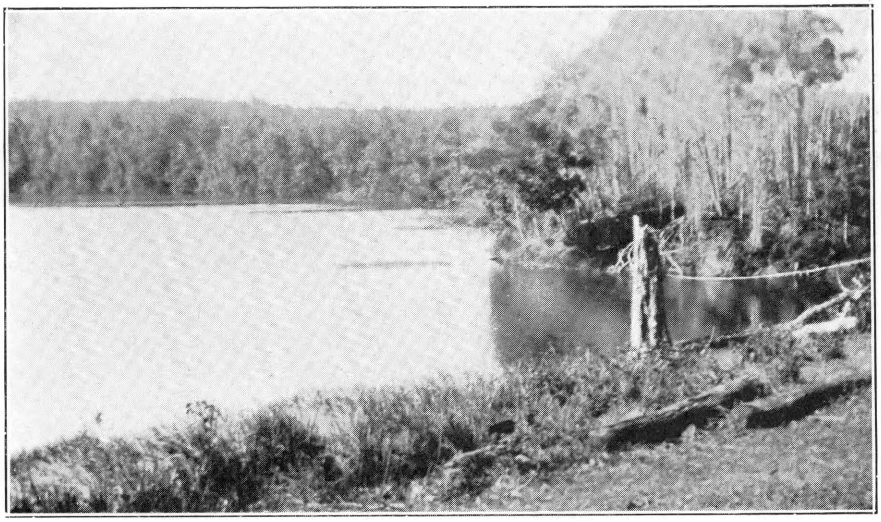
LAKE BARRINE. Section of ash-beds in the volcanic cone.



LAKE BARRINE. Luxuriant rain-forest conceals the crater wall.



Terraces along Mulgrave River, half-mile South of Gordonvale.
The upper 75, the lower 30 feet above river bed.



Lake Eacham. Crater Lake.

[*Face page* 148.]

THE SURFACE TEMPERATURE OF MORETON BAY.

By Charles Hedley, Scientific Director of the Great Barrier Reef Committee.

No. 15.

It has been often stated that the limits of the Great Barrier Reef are set in the north by increasing muddiness of the water, due to the discharge of the Fly and other Papuan rivers, and in the south by increasing cold, due to higher latitude. The next question to answer is exactly how much mud, exactly how much cold, is here meant. Because various genera of coral differ considerably from one another in the amount of mud or of cold that each can endure, the problem becomes complex in its detail.

Meanwhile it is an advance to say that though corals approach no nearer to the Fly estuary than Bramble Cay, yet at that point they grow luxuriantly and endure a muddiness indicated by the opacity meter (see *ante,* p. 65) as disappearance at 22 feet.

Though Lady Elliot Island is the most southern of islets wholely composed of coral, yet some coral persists as far south as Moreton Bay. At Peel Island there is a bank, which can hardly be termed a "reef," where several genera of coral build large, though widely spaced corallia. This I have examined and hope to describe in detail in the future. At Flinders Reef, off Cape Moreton, is another coral cluster described as of vigorous growth but which I have not seen. The most southern example of Tubipora known to me came from this place. We can now say that these southernmost corals endure a minimum temperature of 60° Fahrenheit for a few days in mid-winter.

For the temperature readings here published I am indebted to the kindness of Captain V. B. Forrester, Portmaster, and of Mr. W. Hamilton, Chief Clerk of the Marine Department, who procured them at my request.

The point of observation is the Pile Lighthouse, situated on the eastern side of the entrance to the Brisbane River bar, the geographical position of which is 27° 19′ south latitude and 150° 13′ east longitude. For many years tidal records have been registered here. Peel Island is about 16 miles south-east of the Pile Light, and Flinders Reef about twice as far to the north-east.

The readings and records were made most carefully by the Senior Lighthouse-keeper, Mr. H. Stanford, and in his absence by an assistant keeper. The readings were regularly taken at 9 a.m. for a year. A bucket was lowered to about 6 feet beneath the surface of the sea, and was left there for about five minutes. Then it was drawn up and the thermometer specially supplied for the purpose by the Meteorological Bureau was immersed in the bucket for two or three minutes before being read. Readings from June to December inclusive were taken in 1924, those from January to May in 1925.

The highest reading is 82° on the 25th February. Several days in June, one in July, and one in August have a minimum of 60°. This temperature chart is singularly equable and is probably controlled by the great ocean current outside the coast.

It is interesting to compare the Moreton Bay table with that of Sydney (Hedley, Journ. Roy. Soc. N.S. Wales, XLIX., 1915, p. 19). There a minimum of 50° has excluded all shore corals except Plesiastræa and Cylicia.

—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1st	78	75	79	73	70	65	61	63	65	70	74	74
2nd	76	75	78	73	70	66	61	64	66	68	73	75
3rd	78	76	77	72	68	66	60	63	67	69	73	75
4th	78	75	78	73	69	65	61	63	68	70	75	73
5th	77	76	74	73	68	66	61	61	67	70	74	73
6th	75	76	74	73	67	66	61	60	65	70	73	74
7th	78	76	77	73	67	64	62	61	67	69	73	75
8th	77	76	77	73	67	63	62	62	65	70	73	74
9th	77	76	76	74	67	61	62	63	66	70	74	73
10th	77	76	74	74	67	62	63	62	66	70	74	73
11th	77	76	74	74	66	62	63	62	67	70	74	75
12th	77	77	77	72	65	63	62	62	66	69	75	76
13th	77	77	76	72	66	63	61	62	68	71	76	75
14th	78	78	75	72	66	63	62	63	70	72	74	75
15th	76	78	73	72	65	63	62	63	69	71	75	76
16th	78	80	73	72	66	63	62	61	68	71	74	75
17th	78	79	73	73	65	63	63	63	70	73	73	73
18th	76	79	73	71	67	63	63	63	70	70	74	72
19th	76	79	74	70	66	62	64	62	70	69	74	74
20th	77	80	75	70	66	60	63	64	71	72	75	73
21st	76	80	73	70	67	60	63	63	70	70	74	75
22nd	75	79	74	69	67	60	62	64	70	73	75	74
23rd	74	80	75	69	66	61	62	64	69	70	75	75
24th	74	79	74	70	67	61	63	65	70	71	75	75
25th	75	82	73	70	66	61	63	65	69	72	74	74
26th	73	80	74	69	66	60	63	65	70	73	74	74
27th	75	78	74	69	66	61	64	67	70	74	75	74
28th	74	77	73	69	65	60	62	66	71	74	76	74
29th	76	..	74	69	65	61	63	66	71	73	75	75
30th	76	..	72	69	64	61	64	64	70	73	75	75
31st	76	..	72	..	65	..	64	66	..	73	..	78

THE QUEENSLAND EARTHQUAKE OF 1918.

By Charles Hedley, Scientific Director of the Great Barrier Reef Committee.

No. 16.

The greatest earthquake to shake Queensland, since European colonisation, was that which happened early in the morning of 7th June, 1918. Apparently it was of tectonic, not volcanic, origin.

Unfortunately, Queensland was then and still is unprovided with any apparatus to record seismic phenomena.

The basis of this paper consists of replies to a request from Dr. E. F. Pigot, broadcasted by the Queensland Press, for details by local observers. Many ladies and gentlemen, though untrained and without expert knowledge, have furnished valuable information. Scientific records of the disturbance are confined to those taken in his observatory at St. Ignatius' College, Riverview, Sydney, by the Rev. Dr. Edward F. Pigot, S.J.

Newspaper correspondents reported this earthquake over a wide area of South-east Queensland, extending from Tambourine Mountain in the south to St. Lawrence in the north, and from the sea to Roma in the west.

At the Riverview observatory the longitudinal waves arrived at 4 hrs. 16 min. 53 sec., and the distortional waves at 4 hrs. 18 min. 38 sec. The maximum swing of the recording needles amounted to 78 mm. (over 3 inches).

Dr. Pigot calculated the epicentre of the earthquake as 1,180 kilometres (610 miles) N.N.E. of his observatory. This pointed to a position on the continental shelf, north of Hervey Bay, and east-south-east of Keppel Bay. This place already has an interesting history; near here the submarine cables connecting Gomen in New Caledonia with Bundaberg have been broken so often that the route is now abandoned. Here Captain Sharp, of the cable steamer "Iris," mapped (Proc. Linn. Soc. N.S. Wales, XXXVI., 1911, p. 18) an area of 100 square miles which has sunk in places for 200 fathoms since 1869.

Probably other tremors, too insignificant for attention, have proceeded hence at other times.

It was remarked with surprise that sometimes observers nearer to the earthquake focus felt a lighter shock than others more remote. In Brisbane, Dr. Walkom noticed that few people whose houses were built on schist rock felt any shock, though other people, whose homes were on shale or sandstone, were awakened by it. This seems an ordinary feature of earthquakes. During the great Japanese earthquake of 1923, Davidson (Geogr. Journ. LXV., 1925, p. 43) observed that "In Tokyo the intensity of the shock was three times as great on soft alluvial soil and made ground as on the harder rock elsewhere."

This earthquake is remarkable for having set up a long continued series of lesser shocks along the Leichhardt Range, high ground of Permo-Carboniferous strata, which parts the waters of the Dawson on the west from those of the Burnett and Calliope rivers on the east. Around this after-shock centre at about 100 miles from the sea rumblings, like the Barisal guns of India, and small quakes, both unheard, unfelt a few miles away, persisted for many weeks. Observers a few miles apart sometimes received particular sounds or shocks from diverse or opposite directions, or one event would appear sharp at one place and faint at a short distance. This restricted occurrence indicates local, shallow, and separate origins.

It would seem that the primary shock disturbed the hills, and the consequent minor disturbances were manifested by the secondary shocks and noises. A more definite suggestion is that the range was upheaved by the initial impulse of 7th June, and that to balance this movement, in whole or part, numerous local subsidences followed, each fall expressed by quake or rumbling.

Camboon, in the after-shock area, is marked by W. H. Bryan (Proc. Roy. Soc., Qld., XXXVIII., 1925, fig. 2) on the summit of a main anticlinal axis which dates from the close of the Mesozoic. These observations indicate that the vitality of that anticline is not yet extinct.

By a fortunate coincidence the correspondent who was the nearest to the earthquake epicentre happened not only to be wide awake and at work, but to be an excellent observer. It is interesting to note that the undulations are described as coming precisely from the direction of the sunk sea floor where the cables snap. At about 4.20 a.m. on 7th June, Mr. C. M. Martin, of Gooburrum, a few miles north-west of Bundaberg, was engaged in milking; he was startled by "a terrible rumbling on the roof," followed by a noise like thunder, which lasted about twenty seconds. During this noise a concrete floor seemed to move from east-north-east to west-south-west. The sway of the ground seemed to carry everything a foot or eighteen inches, first to the western side, then back and back again. A hurricane lamp hung from a rafter swung east-north-east to west-south-west and oscillated for five minutss after the shock.

A friend of this writer who that morning was leading home a horse from the Gin Gin (about 50 miles west-south-west) show said that the fences along the road rattled and branches shook as if in a gale.

Several observers wrote from the town of Bundaberg. The Rev. J. D. Kelly remarked that the tremor at Bundaberg was a severe one, and lasted for half a minute. All the clocks in the town stopped. People clung to their rocking beds to save themselves from being thrown on the floor. The beds first rolled and then "seemed to buck a bit."

Mr. F. W. Faithful, of Bundaberg, noted that the force of the earthquake threw small ornaments down from a sideboard. Two large Italian figures previously facing east-north-east were found, after the earthquake had passed, to have rotated till they faced north-north-west.

To another observer very little farther away than those already quoted the earthquake appeared much slighter. Mr. C. Walsh, of Murray's Creek, 6 miles north of Rosedale Railway Station and 20 from the sea, noted the event immediately after in a diary. The shock was received by him as an atmospheric disturbance. The house rattled, glasses on the shelf jingled, and water in a 1,000-gal. iron tank was agitated. Mrs. Walsh "could hear the noise coming." Not till afterwards did Mr. Walsh realise that an earthquake had happened. Even then he had difficulty in believing that the shock had upset a can full of cream on a neighbour's farm three-quarters of a mile away.

At Degilbo, on the Gayndah line, about 50 miles south-south-west of Bundaberg, Mr. V. R. Harris reported that a large eight-day clock moved to one end of its shelf from south to north. A pot plant fell off its stand, falling from south to north.

At Crohamhurst, near Beerwah, about 50 miles north of Brisbane, Dr. C. Buchanan made the following observations:— "Two sharp shocks were felt at Candle Mountain on 7th June, about thirty seconds apart and lasting seven or eight seconds each, the second one the more severe. Watch checked by observation on 8th June giving the actual calculated time of the first shock as 4.16. Two or three slight tremors followed in the course of the next quarter-hour. The motion was almost entirely vertical, but the direction of the horizontal motion was from west to east. Beds were shaken sufficiently to waken sleepers and to suggest that there was danger of being thrown out. Shingles could be heard working in the roof. There is said to have been a clap of thunder before the first shock. The night was fine and warm; in places rain fell.''

Candle Mountain is an old volcano. This is the third shock felt there since 1913, but the other two were slight. One was preceded by a loud noise like a fall of rock.

The earthquake had lost some of its force on reaching Brisbane. Mr. J. F. Catley, residing at Bulimba Ferry, was awake and reading when the shock occurred at 4.15 to 4.20. When the doors and windows rattled he supposed it to be the consequence of a wind-squall, but he recognised the real cause when he noticed the water move in a tumbler on the table. From this he saw that ''the earth dipped to the south, then righted itself, and then dipped to the south with a distinct reel to the south-east, righted, then dipped to the south, righted, and dipped again to the south, and steadied itself with tremors.'' Thus four distinct dips were noted. The diameter of the tumbler was three inches and the dip from $\frac{1}{8}$ to 3/16 inch.

Mrs. Feenaghty, of Wooloowin, was awakened by the rocking of the house, giving a sensation like swinging in a hammock. There was no noise of window rattling or crockery shaking, and it was with difficulty that she realised that an earthquake had passed.

Mr. C. S. Bennett was informed that the sea at Emu Park and Yeppoon ''made great noises,'' also that ''Rockhampton and Mount Morgan suffered.''

At Toowoomba, Mrs. Eva N. Aitken found that her pictures hung on east and west walls were displaced, ''slanting half an inch east,'' while those on other walls slanted half an inch to the north. Tea cups were displaced on their saucers; they, too, slanted eastwards.

The most western correspondent was Mr. C. S. Bennett, at Banana, 140 miles inland from Bundaberg. Though a heavy sleeper, he was awakened by violent shaking of his bed. A big shock came at 4.25, followed by two lesser ones in rapid succession, accompanied by loud rumblings. Large earth waves were followed by heavy dust and a clouded sky. In another house, doors were flung open and slammed shut and the furniture danced about. At a two-storied wooden hotel the lamps quivered for five minutes and the floor opened out. The direction of the earth waves ranged from east by south-east to south. Sleepers who were camped out in the bush reported that they were rolled over by the earthquake.

At Rannes, large logs of wood partly embedded in the soil were rolled clean out.

Mr. Lionel C. Ball did not himself experience the earthquake, but supplied notes from residents of Mount Cannindah, on the Upper Burnett, about 70 miles west of Bundaberg, and north of Eidsvold. The first shock of 8th June was at 4.30 a.m. This shook the houses, woke people, and was followed by a rumbling noise. Another shock followed in a quarter of an hour, and four more before 6 a.m. A seventh happened at 8 p.m. that evening, and again another at 4.30 a.m. on Saturday, 9th June, making a total of eight distinct shocks in twenty-four hours.

A correspondent writing to the "Grazier" newspaper from Camboon, a township 150 miles north of Chinchilla, and 50 miles from Banana, thus relates her experiences:—Awakened by a very severe shock at 4.15 a.m. on 8th June, she jumped out of bed and found the floor rocking so under her feet that she could scarcely stand. The wooden house shook as if every nail in it would be drawn loose. The noise of the shock died away, travelling north-east. At intervals of ten minutes a second and a third milder shock followed. Four more occurred before 9 a.m.

All day long rumbles like that of distant rolling thunder, varying in intensity, were heard from the north-north-east. More than thirty such were counted. These rumbles and tremors continued on the next day, and it was remarked that the house shook at the tremors but not at the rumblings.

Mr. F. M. Bell, also writing from Camboon, gives a history of the long succession of after-shocks and of their various and superficial origin. The shocks began, as elsewhere, on 7th June, at 4.15 a.m., with a very severe earth tremor accompanied by a loud noise like deep rolling thunder, which, after lasting for fully a minute, gradually died away in the east. Before 9 a.m. that morning seven slight tremors were felt, and during the day about fifty rumbles, resembling distant thunder, were heard in the north-north-east. Similar slight shocks and rumblings continued to 1st July, when at 9.45 a.m. there was a shock severe enough to shake the house. This was followed by another such on 3rd July, at 10 a.m. Both noise and movement then ceased till 20th August, when another slight earth tremor happened at 8.5 p.m. which seemed to come from the north-eastern quarter. A succession of rumbles, mostly during the night, followed for the next three days.

Similar shocks and rumbles were heard and felt at Cracow and Rawbelle stations. The manager at Kroombit station observed the rumbles to come from a south-west direction, while to Camboon they came from north-east. In places 30 miles apart the same shock may appear to one as slight, to the other as severe. The rumblings also are heard louder in some places than in others.

Both shocks and rumblings were confined to the range dividing the Dawson and Don Rivers from the Burnett and Calliope rivers. At a distance of 30 miles on either side of this range no earthquake was heard or felt since the last shock of 9th June.

From Wingfield, a selection on Rawbelle station and 40 miles from Banana, Mr. Burnett Hindmarsh gives his experiences:—The shock of 7th June was severe; buildings rattled and pictures fell. Then followed a noise in the north-west like the firing of heavy cannon. Before daylight there were four more shocks, and the noise was heard from time to time all day. At 6.45 p.m. the buildings were again shaken by two shocks. On 11th June, at 6.45 a.m., another rather severe shock took place, and another at 2 a.m. on 18th June. On 20th August, at 8.30 p.m., a distinct earthquake was accompanied by a rumbling noise in the north-north-east. Some people sitting on the ground round their camp fire felt the earth quiver.

Some authors (Andrews, Journ. R. Soc., N.S.W., XLIV., 1911, p. 429) consider that the direction of movement in this region has been mainly outwards from the land to the sea. In the case of the 1918 earthquake the force moved in the contrary direction.

REPORT OF THE SCIENTIFIC DIRECTOR FOR 1924.

No. 17.

His Excellency Sir Matthew Nathan, P.C., G.C.M.G.,
Chairman, Great Barrier Reef Committee, Brisbane.

Your Excellency,—

I have the honour to present my report on the work of last year.

My engagement as Scientific Director to the Great Barrier Reef Committee commenced on the 1st April, 1924. A few days were spent in Sydney obtaining gear for fieldwork and in discussing our business with members resident in Sydney. I arrived in Brisbane on the 7th and immediately reported for duty.

At the next meeting of the Committee I offered a plan of campaign for the ensuing season of which the members approved. It was suggested—

(1) That the coral growth of Moreton Bay should be examined.

(2) That I should visit a dead reef reported at Bowen by Mr. E. H. Rainford.

(3) That an invitation from Professors Richards and Goddard to accompany their University Excursion to the Capricorn Islands should be accepted.

(4) That I should afterwards accept an invitation from Captain Bennett and the Naval Board to join H.M.A.S. "Geranium" on a surveying cruise.

(5) That I should make preparations for the production of a handbook of the corals of Queensland.

(6) That I should complete for the press a bibliography of the Great Barrier Reef.

Field work was commenced at the end of April by a trip to Moreton Bay. Professor Richards and I inspected a thriving reef on which grew no less than fifteen different kinds of coral. As the temperature endured by this southern outlier of the coral fauna is a matter of importance, it has been arranged to take daily readings of surface of the sea for a whole year. I hope to prepare a detailed account of this reef for publication.

My next journey was early in May, to Bowen, to observe the dead reef reported by Mr. Rainford. This proved to be a matter of far greater importance than anticipated. A problem which had puzzled Darwin was why, under conditions apparently favourable, coral reefs should be absent or meagre. The explanation is now obtained. Briefly, I found that a flourishing reef had been suddenly and completely destroyed by a deluge of rain, that it had been washed away by the waves and never revived. The tale of destruction was studied in detail and my report has been published in our Transactions.

Early in June I accompanied Professors Richards, Goddard, and Skeats to North-West Island in the Capricorns. A large series of specimens repaid our exertions.

Mr. F. Jardine, B.Sc., the holder of a Science Research Scholarship from the University of Sydney, who carried out scientific investigations as one of our officers for the time being, on the nomination of the University of Sydney, joined our service late in June. He has devoted himself to the study of Coastal Physiography, commencing with the islands in and round Keppel Bay, continuing with Torres Strait, and concluding with an area near Cairns. Reports on all these are promised but have not yet arrived.

July and August were spent on board H.M.A.S. "Geranium," where I enjoyed the most cordial assistance in scientific work from the commander and his officers. An area usually inaccessible was examined. By the help especially of Dr. Paradice a large zoological collection was assembled.

A line of high islands between Dunk and Fitzroy Islands were first surveyed, and then an outer tier of reefs parallel but eastward of the coast. Two members of our Committee were honoured by Captain Bennett, who named one uncharted reef McCulloch and another Hedley Reef. I had an opportunity of viewing a hundred miles of the Great Barrier from a sea-plane, and I received the impression that the reefs are smaller and set farther apart than any small-scale map would convey.

The section of the reef that I saw from the "Geranium" between the parallels of 17 and 18 S. latitude is peculiarly destitute of sandbanks; for the space of fifty miles no dry land appears on the reefs between Beaver Cay in the south and Scott's Reef in the north. This is in strong contrast to the richly vegetated cays in the (perhaps more stable) areas of Torres Strait and the Capricorns. since forest growth on a cay is a sign of maturity, then absence of trees and even of sandbanks points to a youthful stage, and may indicate that this section of the Great Barrier Reef is recovering from a drowning movement.

Linear packing of the reefs on this front of the Barrier seems to reflect rock foundation from a shallow depth. The long N.-S. stretch of the high Palm Islands resembles the stretch of the chain of reefs from Flora to Ellison.

The charts of this section are not detailed enough for elaborate study, but I remark that between 50 and 100 fathoms the margin is unusually narrow, in other words exceedingly steep. So that here the edge of the continental shelf is better expressed by the 40- than by the 100-fathom contour line.

A series of observations with the requisite illustrations were presented for publication. These deal with the structure and movement of the coast, with beaches of coral rock, and with a device for measuring the opacity of water.

At the end of August I parted from my hospitable hosts of the "Geranium" with much regret.

A few days spent in Cairns were devoted to the study of a small volcano as yet unrecorded in scientific literature. This, called "Greenhill," though extinct is quite recent, and so little denuded that the crater is still visible. This tuff-cone has obviously barred the Mulgrave River from a former estuary at Cairns and driven the stream to its present southerly bed.

With Mr. F. Jardine I then joined the lighthouse vessel, "Karuah," as the guest of Mr. Cowlishaw. While the officers of that department were erecting a tower on Bramble Cay we spent five weeks collecting and observing. An attempt was made to probe the underlying strata with a hand-drill but without success.

A method by which the frigate bird forces its victims to surrender their catch of fish seems unrecorded. It appears, from numerous maimed birds on the beach, that when the bandit fails to make his prey disgorge their fish he seizes the outstretched wing in his beak and with a jerk dislocates a joint.

A visit was paid to Darnley Island, where I was much interested in a huge ash-crater which had been much worn by denudation and upon which subsequent lava-flows had intruded.

Jukes had seen this crater, but failed to recognise its nature. Much coral torn from underlying beds had been ejected by the volcano. These were arranged tier above tier in the crater-walls set among ash and pumice.

For the issue of reports and memoirs by this Committee, our parent Society has instituted a new series of publications distinguished as "Transactions."

Our fellow member, Mr. Bassett Hull, has collected along various points of the coast and sent to us an especially interesting series from Flinders Island. The Director of the Queensland Museum has kindly granted us the use of a store-room for zoological material. The Government Botanist has kindly received all our botanical material and made arrangements for reports on it.

Efforts have been made to interest the general public in our work. A popular lecture on the Great Barrier Reef was given by the Chairman at Rockhampton, another at Mount Morgan by Professor Richards, and another on the same subject at Thursday Island by the Scientific Director. Two popular articles profusely illustrated, one describing a flight over the Barrier Reef in a seaplane, the other, the work of constructing a chart, were broadcasted to the Australian Press in October and appeared in all the capital cities. Other articles were written for newspapers in Brisbane and Sydney.

In November, as arranged previous to my engagement, I left for a four months' trip through Central Africa.

Yours faithfully,

CHARLES HEDLEY, Scientific Director.

24th April, 1925.

CORRESPONDENCE.

Extract from letter addressed to "The Secretary, Barrier Reef Committee," by Mr. E. H. Rainford, Bowen:—

* * * * * *

"I desire to be permitted to point out what I presume to consider a mistaken conclusion in the reprint No. 2 on Holbourne Island. Although not definitely stating so, the authors convey the view that the destruction of the fringing reef was due to very recent emergence. Having known Holbourne Island since 1907 and made many trips to it, at intervals, remaining once a whole month on the place, I must express my disagreement with this idea. The fringing reef on Holbourne was destroyed in 1918, at the same time that other fringing reefs were destroyed throughout the Whitsunday Group and from the same cause. Since I first visited Holbourne the puddingstone and conglomerate benches, testifying to recent emergence, have remained in precisely the same condition and elevation, but the fringing reef flourished down to 1918. The islet on the south-eastern point of Holbourne is connected to Holbourne by a coral platform which at low spring tides—say zero to 6 inches on the tide gauge—would be just awash; on this platform used to flourish very fine colonies of *Tubipora musica.* This platform is to-day at precisely the same elevation as fifteen years ago—i.e., just awash at low water springs—but the fringing reef was flourishing up to six years ago. Again, had emergence killed the reef the fact would have vitiated the correctness of all the tide gauges along the coast, which has not taken place unless, indeed, it was argued that emergence took place only at Holbourne Island, which is in the highest degree improbable."

RECENT LITERATURE ON THE GREAT BARRIER REEF.

Australian Pearl Fisheries—C. Hedley. The Australian Museum Magazine, ii., pt. 1, 1924, pp. 5-11, pl. 1.

The Great Barrier Reef of Australia—C. Hedley. Natural History, xxiv., 1924, pp. 62-67. Two plates.

Destruction of the Whitsunday Coral Reefs, Queensland—E. H. Rainford. The Australian Museum Magazine, ii., pt. 5, 1925, pp. 175-177.

The Great Barrier Reef—Col. Sir Gerald Lenox-Conyngham and F. A. Potts. The Geographical Journal, lxv., pt. 4, 1925, pp. 314-334. Four plates.

A Naturalist in North Queensland—A. F. Basset Hull. The Australian Zoologist, iv., pt. 1, 1925, pp. 9-16, pls. iii.-v.

GREAT BARRIER REEF

STATEMENT OF RECEIPTS AND PAYMENTS

RECEIPTS.

	£	s.	d.
1923. 30th June—			
To Subscriptions to date	17	17	0
,, Bank Interest	0	1	1
	£17	18	1
1923. 1st July—			
To Balance b/d	10	4	7
1924. 30th June—			
To Subscriptions to date	1,506	12	0
,, Government Grant	500	0	0
,, Interest from War Loan Bonds	11	5	0
	£2,128	1	7
1924. 1st July—			
To Balance b/d	1,901	10	3
1925. 30th June—			
To Subscriptions to date	466	11	0
,, Government Grant	500	0	0
,, Bank Interest	15	15	4
,, Interest from War Loan Bonds	22	10	0
	£2,906	6	7

RESEARCH FUND.

FOR PERIOD ENDED 30TH JUNE, 1925.

PAYMENTS.

	£	s.	d.
1923.			
30th June—			
By Office Expenses—			
Petty Cash, Postages, &c.	4	7	6
Stationery, Printing, and Office Requisites	3	6	0
,, Balance c/d	10	4	7
	£17	18	1
1924.			
30th June—			
By Expenses—			
Office—			
Petty Cash, Postages, &c.	7	6	5
Stationery, Printing, and Office Requisites ..	7	11	7
Research—			
Salaries	166	13	4
Equipment and Sundries	30	0	0
Shelving for Specimens	15	0	0
,, Balance c/d	1,901	10	3
	£2,128	1	7
1925.			
30th June—			
By Expenses—			
Office—			
Petty Cash, Postages, &c.	19	8	6
Stationery, Printing, and Office Requisites ..	19	7	3
Research—			
Salaries	308	6	8
Equipment and Sundries	149	2	1
Shelving for Specimens	6	5	4
,, Balance at Bank	2,403	16	9
	£2,906	6	7

W. M. L'ESTRANGE, Hon. Treasurer.
1st July, 1925.

Index.

A. J. CUMMING, Government Printer, Brisbane

Prepared for the GREAT BARRIER REEF COMMITTEE at the Survey Office, Brisbane,
by courtesy of the Surveyor-General.